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CACDA GROUND COMBAT MODEL

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COMBAT OPERATIONS ANALYSIS DIRECTORATE

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Directorate of Combat Operations Analysis
US Army Combined Arms Combat Developments Activity
Fort Leavenworth, Kansas 66027

CACDA GROUND COMBAT MODEL

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ACN 52700

ABSTRACT

This report documents a quick-running, low-resolution ground combat model developed at the US Army Combined Arms Combat Development Activity (CACDA). This model determines firers, targets, engagements, kills, data update, and specified output for each time step of a tank-antitank battle. A model overview is presented, and potential model applications are discussed. Data requirements, model mathematics, and computer coding are included. The model should be a useful tool for ranking weapon mixes to determine sets of best candidates for more detailed considerations. The model can also be used in an interactive gaming environment.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Mrs Elizabeth Etheridge, Mr Ronald Magee, and Mr Richard Rinkel for their experienced counsel and willing help. Their advice and assistance were used for improvements to the model and report throughout; naturally, the responsibility for any further problems rests with the authors.

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CHAPTER 1

INTRODUCTION

1-1. PURPOSE. This paper describes a quick-running, low-resolution ground combat model operational on the Hewlett-Packard (HP) 9830 computer. The model simulates battalion-level tank/antitank combat, including the attacker's advance rate.

1-2. BACKGROUND. COL Reed E. Davis, Jr. originated the model at the US Army Combined Arms Combat Development Activity (CACDA), Fort Leavenworth, Kansas, in 1977. Part of the impetus for model development was CACDA's experience in preparing for the Antiarmor Systems Program Review (ASPR). A responsive and credible war game, flexible enough to deal with a range of issues and visible enough to be understood quickly by decisionmakers, would have been most useful to the ASPR effort. COL Davis published a version of the model (reference 1) operational on HP 67/69 hand-held calculators. Subsequently, the model was installed at CACDA on the HP 9830 computer to support the Maneuver and Fire Support (MANFIST) study. In this application, the model was used in a process to screen numerous alternatives prior to a large scale war gaming effort. Simulations of artillery, the Copperhead system with ground locating laser designators (GLLD), FASCAM mines, attack helicopters, and air defense were added to the model for the MANFIST application.

1-3. APPLICABILITY. The Ground Combat Model (GCM) is a quick-running, gross representation of ground combat. When all input is preplanned, a 20-minute mid-intensity battle can be run, in 1-minute time increments, in 75 minutes. The model should be useful for ranking weapon/force mixes to determine a set of best candidates for more detailed simulation or war gaming. It can also be applied in an interactive gaming environment to satisfy experimental design requirements for real time casualty assessment.

1-4. MODEL COMPARISONS. Output from this analytical model compares favorably with that from CARMONETTE, a large-scale simulation model, when analogous scenario input is used.

a. CARMONETTE was used recently at CACDA to support the Division Restructuring Evaluation (DRE). Representative runs from that study were selected; and similar values for such elements as weapon numbers, artillery firings, and terrain factors were used in a Ground Combat Model run. Measures of effectiveness from the two models are shown on figures 1-1 through 1-4. Figures 1-1 and 1-2 show that loss rates for both Red and Blue were lower in the Ground Combat Model than in CARMONETTE. The data used in GCM resulted in a less intense battle being modeled. However, the loss rates in the two models behaved in the same way, as indicated by the similar shapes of the loss exchange ratio curves in figure 1-3 and the curves for the surviving maneuver force ratio difference in figure 1-4. The latter two figures also show that the difference between the two models for Red loss rates was slightly more than for Blue loss rates.

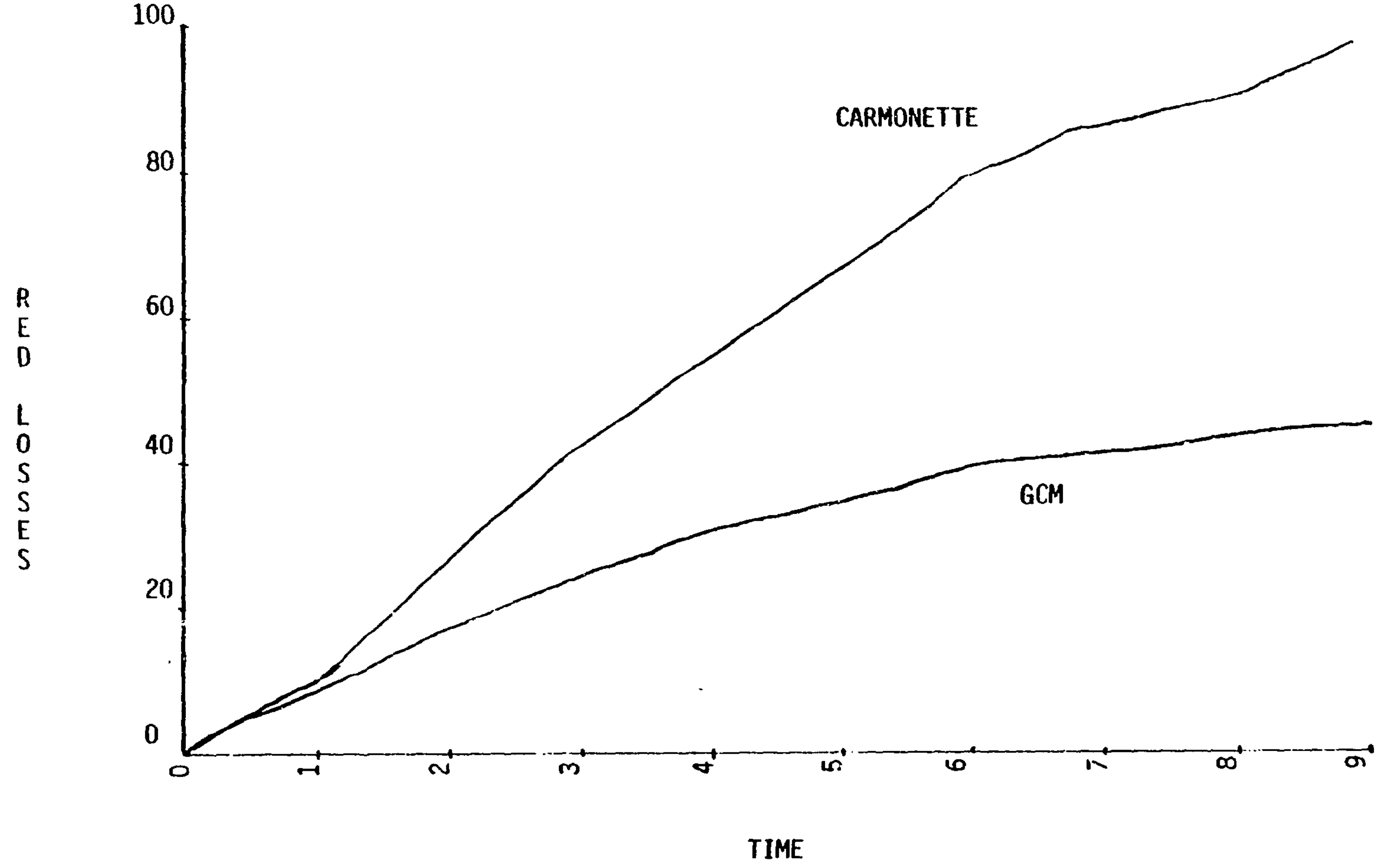

Figure 1-1. CARMONETTE and GCM comparison, Red losses

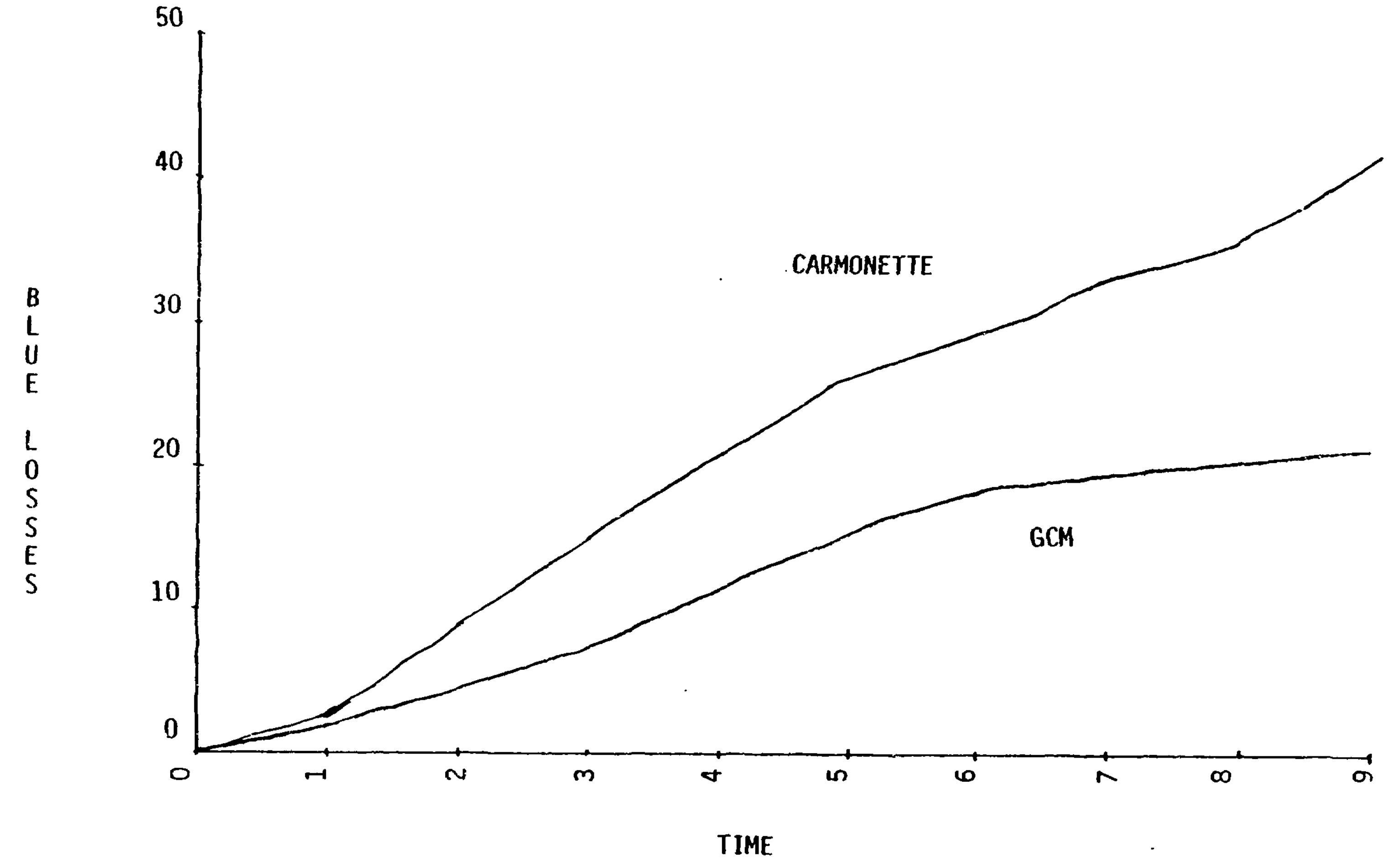

Figure 1-2. CARMONETTE and GCM comparison, Blue losses

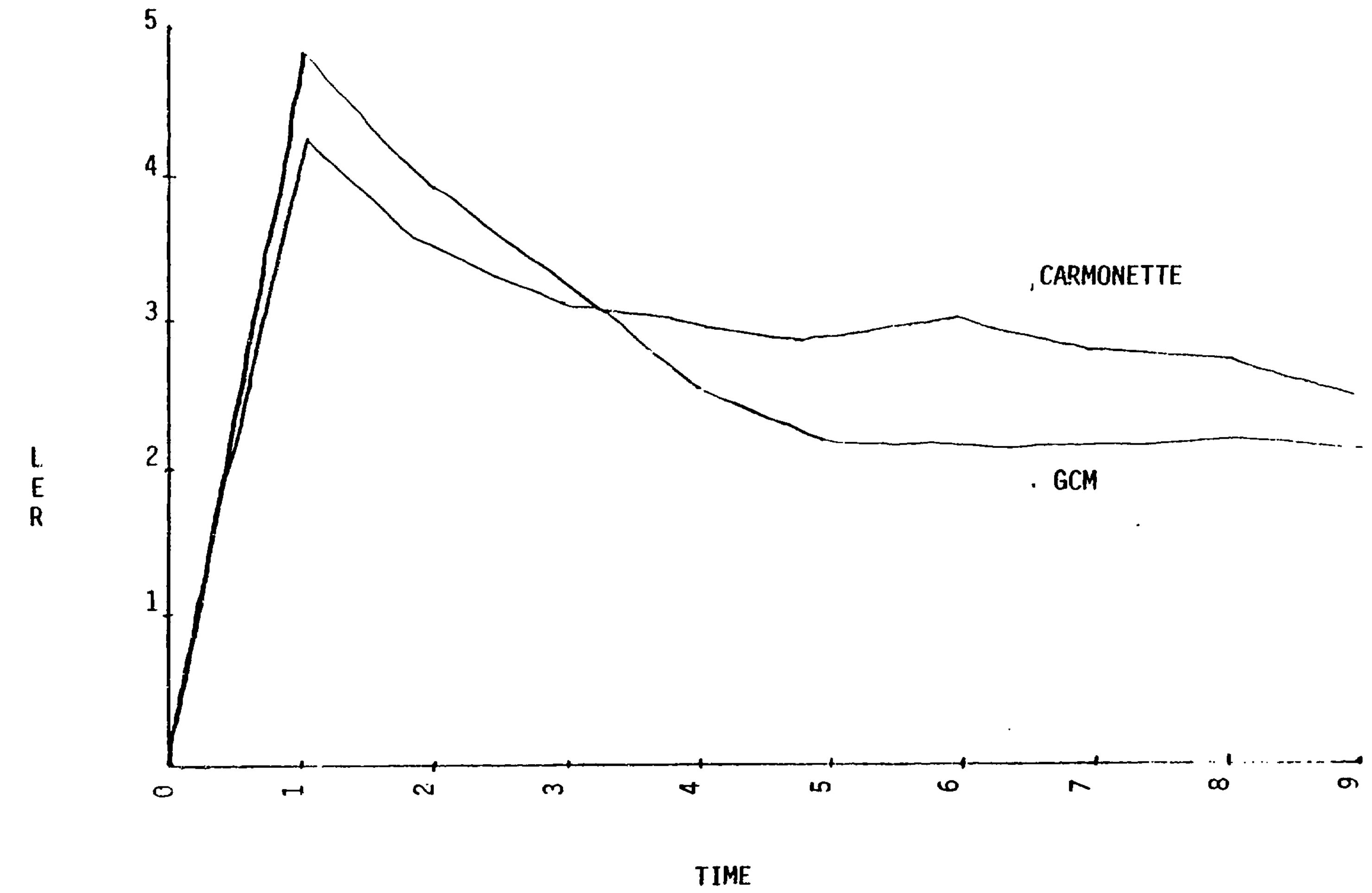

Figure 1-3. CARMONETTE and GCM comparison, loss exchange ratio (LER)

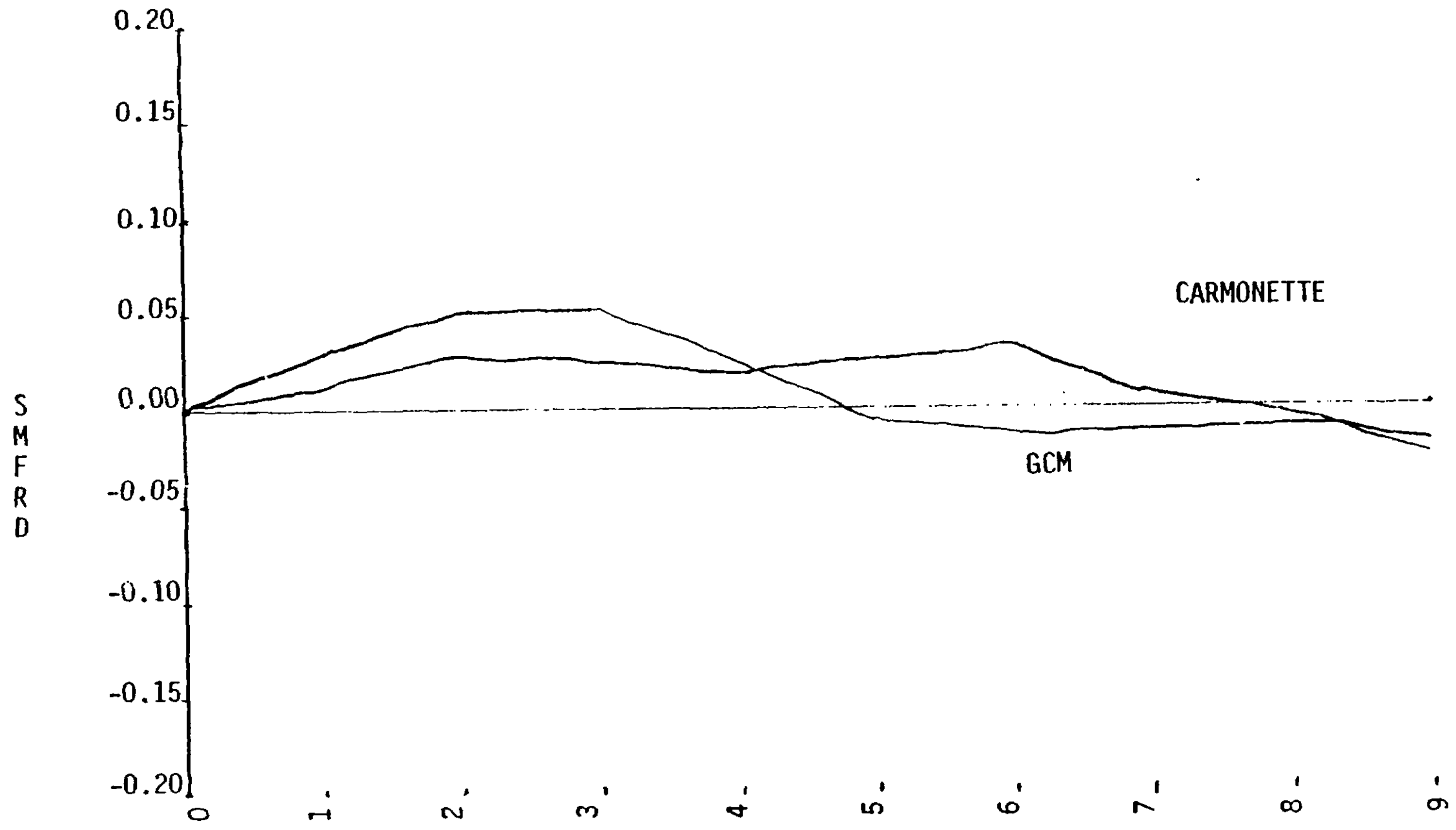

Figure 1-4. CARMONETTE and GCM comparison, surviving maneuver force ratio difference (SMFRD)

b. This comparison indicates that the Ground Combat Model has potential as a tool in the decision process. The use of such analytical models, based on large scale simulation models, to assist in policy decisions is well known (reference 4) and is much less expensive in terms of time, money, and manpower than using the large scale simulation models.

1-5. ORGANIZATION OF PAPER. The main body of this paper presents an overview of the Ground Combat Model in terms of its capabilities, input requirements, output reports, and gaming procedures. This generalized description provides prospective users with sufficient information to make preliminary judgments as to the model's potential applicability to specific problems. Appendixes to the paper contain detailed technical descriptions of input data requirements (appendix A), model routines (appendix B), and output formats (appendix C).

CHAPTER 2

GROUND COMBAT MODEL OVERVIEW

2-1. MODEL CHARACTERISTICS.

a. The Ground Combat Model can be characterized as a low-resolution, quick-running, time-step model. It is scenario dependent and can easily be used in conjunction with map exercises. The model described by this paper considers Red as the attacker and Blue as the defender; however, a Blue attacker, Red defender version is also operational.

b. The weapon types currently represented in the model are Red and Blue tanks, Red and Blue attack helicopters, Red and Blue air defense, BRDM, BMP, TOW, Dragon, Copperhead, FASCAM, and artillery. Killer-victim relationships represented are shown in table 2-1.

c. For each time-step increment, the model considers factors such as the following:

- Number of firers
- Availability of firers
- Number of targets
- Probability of kill given a hit
- Single shot hit probabilities
- Engagement rates
- Probability of line of sight
- Performance degradation due to suppression
- Target detection rates
- Allocation of fires policy for tanks versus softer targets
- Basic loads.

Some of these factors are direct inputs, and others are computed as functions of time or range. Input data for some weapon types must be obtained from pre-processor operations.

Table 2-1. Killer-victim relationships in Ground Combat Model

Killer	Victim					
	[1] Direct Fire	Attack Helicopter	Air Defense	Copperhead	[3] FASCAM	[3] Artillery
[1] Direct Fire	X			[2] X		
Attack Helicopter	X		X			
Air Defense		X				
Copperhead	X		X			
FASCAM	[4] X					
Artillery	X		X	X		

Notes:
1. Includes tanks, TOW, Dragon, BRDM, BMP
2. Ground locating laser designators (GLLD) are given the same vulnerabilities and priorities as targets as the Dragon.
3. Attrited externally (see para 2-2e)
4. Red tanks and BMP only (see para 2-2d)

d. Output statistics obtained for each increment include the following:

- Total committed forces (Blue and Red)
- Current forces (Blue and Red)
- Cumulative losses (Blue and Red)
- Surviving maneuver force ratio difference
- Loss exchange ratio
- Fractional exchange ratio
- Attacker advance rate
- Distance advanced.

2-2. MODEL CONSIDERATIONS.

a. Some of the principal aspects of the model's treatment of ground combat are as follows:

(1) Artillery begins to detect at the first time increment but with degraded performance. This simulates the buildup of information by the forward observers from the start of the battle until the maximum detection rate possible at a specified time. Detection start time for other weapons is controlled through input.

(2) Tanks, TOW, Dragon, the Copperhead's ground locating laser designator (GLLD), BRDM, and BMP are suppressible using the Litton suppression equation (reference 2). Other weapon types, such as air defense and artillery, may be suppressed externally through numbers committed or available.

(3) The attacker's advance rate may be made constant or a function of loss rate ratios. Currently, the attacker's advance is stopped when the percent of attacker losses exceeds twice the defender's percent of loss; however, the battle continues, and the attacker may start to close again after he increases the defender's loss percent (perhaps by calling in heavy artillery) or adds reinforcements.

(4) In the FASCAM routine, BRDMs stay in overwatch. Tanks and BMPs either bull or plow through the minefields.

(5) Artillery and FASCAM are attrited externally by gamer decisions (e.g., on close air support and counterbattery). The other weapon types also may be reduced externally by gamer decision. Output battle statistics, however, are computed using the weapons that are attrited internal to the model.

b. Important considerations with respect to the GCM data base include the following:

(1) Weapon system interactions are represented only in the data base by such considerations as operational engagement rate calculations and in the allocation of fires data. Thus, the input data must be carefully checked for consistency among weapon types.

(2) The model depends heavily on empirical data for detection, engagement, and movement rates. Such data are available for only a limited range of scenarios, terrains, and other environmental conditions. The potential impact of changes in scenario, terrain, and environment must be considered for virtually every data element.

(3) The terrain model (appendix B, paragraph 5) contains good fits to only one terrain statistic, probability of line of sight. Segment length distributions are represented, for example in defining missile abort rates, in the operational engagement rates. Thus, correlated line of sight is not explicitly represented.

2-3. MODEL INPUT.

a. Certain values must be input at the start of each run, including the following:

. Time step increment

. Terrain factors

. Initial range of opposing units

. Formation depths

. Initial number of weapons by type

. Initial and maximum attack speed

. Artillery preparation

. Target priorities (e.g., Red's preference for engaging TOWs over Dragon or Copperhead GLLDs, Blue's preference for BRDMs over BMPs)

. Detection start time for each weapon

. Time at which target saturation occurs with respect to detection.

Since the HP 9830 is an interruptible machine, these values may be changed after the battle starts.

b. Other factors may be input either before or during the battle. These factors, which currently are input during each time period, include the following:

. Number of reinforcing weapons and time of reinforcement

. Percent of attack helicopters employed

. Percent of air defense available

. Number of GLLD-controlled projectiles per GLLD

. Number of FASCAM minefields and Red response (bull or plow)

. Suppression option

. Artillery firings during each time period.

c. Data requirements of the Ground Combat Model are described in detail in appendix A.

2-4. MODEL FLOW. The computer routines and the general flow of the Ground Combat Model are shown on figure 2-1 and summarized below. Detailed descriptions of each routine and definitions of the variables are contained in appendix B.

a. After an initialization of forces and battle situation, the model calculates attrition resulting from weapon engagements, updates forces and status, and commits reinforcements.

(1) Block 1, Initialization. A routine called Control initializes the battle and controls the sequencing of weapon attrition calculations. The initialization is accomplished in part by querying the model operator for a number of initial questions, such as force structures and initial battle range.

(2) Block 2, Artillery. At the start of each time period, the model operator may choose to employ artillery, selecting the type artillery, the number of rounds, and the target type. The model does output a desired number of rounds, which is calculated from an input fraction of kills of the total number of targets found by the model detection routine. For the first time period, the model operator puts in the artillery preparation barrage, if any, then the artillery for the first period. Artillery employment is optional for each time period.

(3) Block 3, Ground to Ground. The ground to ground attrition routines are entered each time period for each weapon (Blue and Red tanks, TOW, Dragon, BRDM, and BMP). The routines consider acquisition, engagement, and allocation of fires in calculating attrition.

(4) Block 4, Helicopter and Air Defense. For each time period, the model operator has the option of employing attack helicopters and air defense. He must input the fraction of attack helicopters to be employed and the operational availability of the air defense.

(5) Block 5, FASCAM and Copperhead. The model operator may elect to employ FASCAM each time period by providing the number of standard (300m x 300m, 90-mine) FASCAM minefields to be employed and the Red response (bulling or

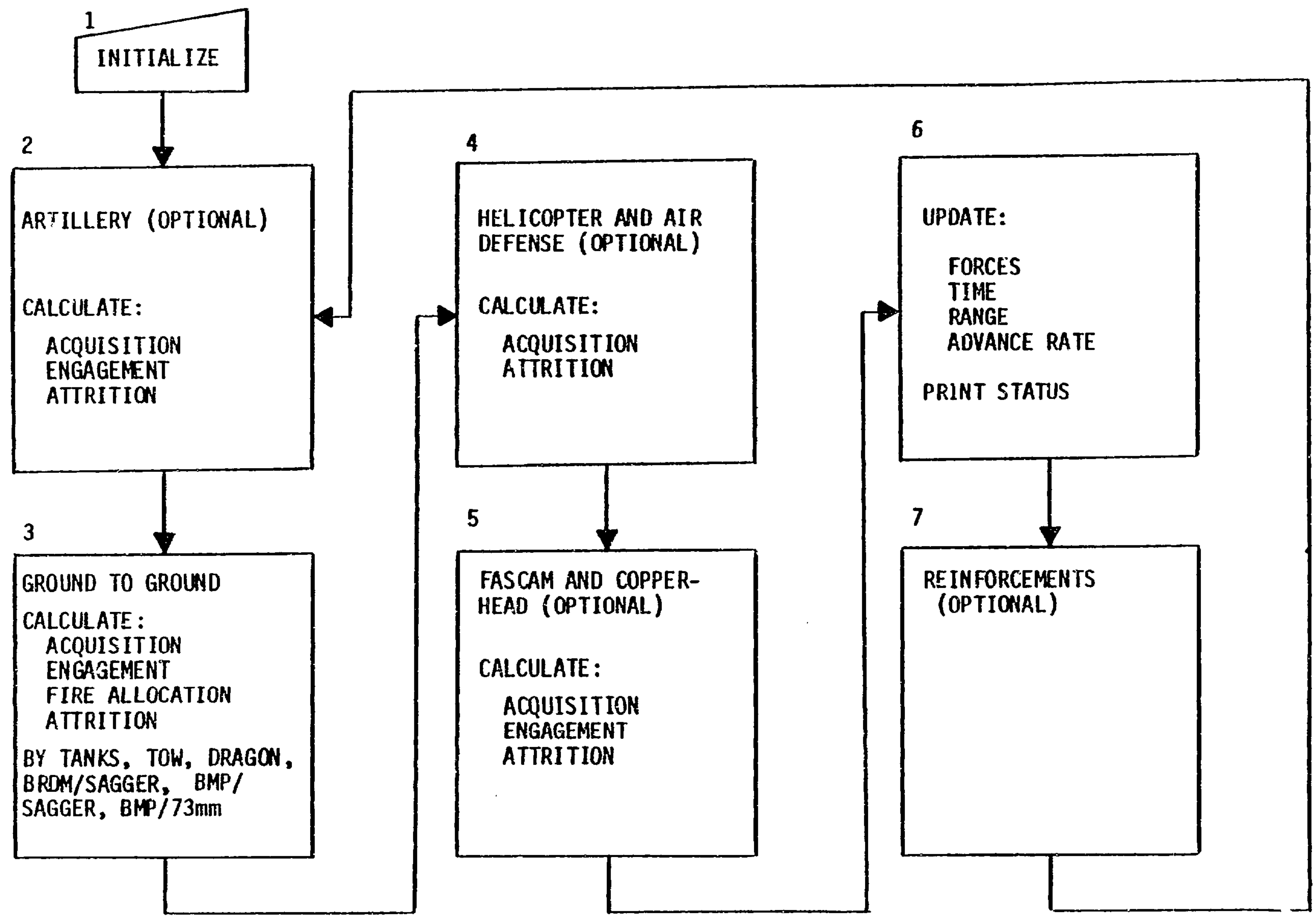

Figure 2-1. Ground Combat Model flowchart

plowing through). Copperhead may be employed by providing the number of rounds per GLLD per minute.

(6) Block 6, Update. After the attrition routines are completed, the forces and time are updated, and the range and advance rate are computed. The various measures of effectiveness (MOE) and force status are printed. If the attacker's advance has been stopped, this message is printed automatically.

(7) Block 7, Reinforcements. At this point the model operator may enter reinforcements for either side.

b. The next time period starts with the artillery routine. The battle continues by time increments until the attacker overruns the defender or the operator stops the battle because of such considerations as percentage losses on either side or time length of the battle.

2-5. MODEL OUTPUT.

a. The measures of effectiveness (MOE) available from the Ground Combat Model include the following:

. Attacker's advance rate (km/min)

. Distance advanced (advance rate x length of time period). If period length is 1 minute, then distance advanced and advance rate are numerically equal.

. Battle range (km)

. Present forces (Blue and Red)

. Total committed forces (Blue and Red)

. Percent losses (Blue and Red)

. Percent surviving (Blue and Red)

. Cumulative losses (Blue and Red)

. Surviving maneuver force ratio difference (SMFRD)

$$\text{SMFRD} = \frac{\text{Present Blue forces}}{\text{Committed Blue forces}} - \frac{\text{Present Red forces}}{\text{Committed Red forces}}$$

. Loss exchange ratio (LER)

LER = ratio of Red losses to Blue losses

. Fractional exchange ratio (FER)

$$FER = \frac{LER}{\text{Committed Red forces/Committed Blue forces}}$$

b. By using the model's graphing program, these MOE may be plotted versus time individually or with MOEs from the same battle or different battles. Sample plots are shown at figures 2-2 and 2-3. Figure 2-2 shows a plot of the MOE, percent Blue survivors, from two different battle runs. Figure 2-3 is a plot of the two MOEs, percent Blue survivors and percent Red survivors, from the same battle run.

c. Output programs are described in detail in appendix C.

2-6. GCM GAME PROTOCOL.

a. Since the Ground Combat Model is designed to make rapid comparisons among alternative forces, certain aspects of the associated gaming must be resolved prior to model initiation. These are basically the areas of scenario definition and gaming rules and include the following specific items:

(1) Terrain

(2) Weather conditions

(3) Force objectives

(4) Initial and subsequent defender battle positions

(5) Attacker routes of advance through area and those to be used in initial attack

(6) Battle termination criteria

(7) Fire support allocation, rates of fire, and suppression effects

(8) Unit movement rates

(9) End of game criteria.

b. The game team can consist of as few as four personnel, but a more practical size is six.

(1) The team must include a Red force commander and a Blue force commander, each of which is concerned with the tactics and employment of his forces. These officers should have some expertise in maneuver tactics for

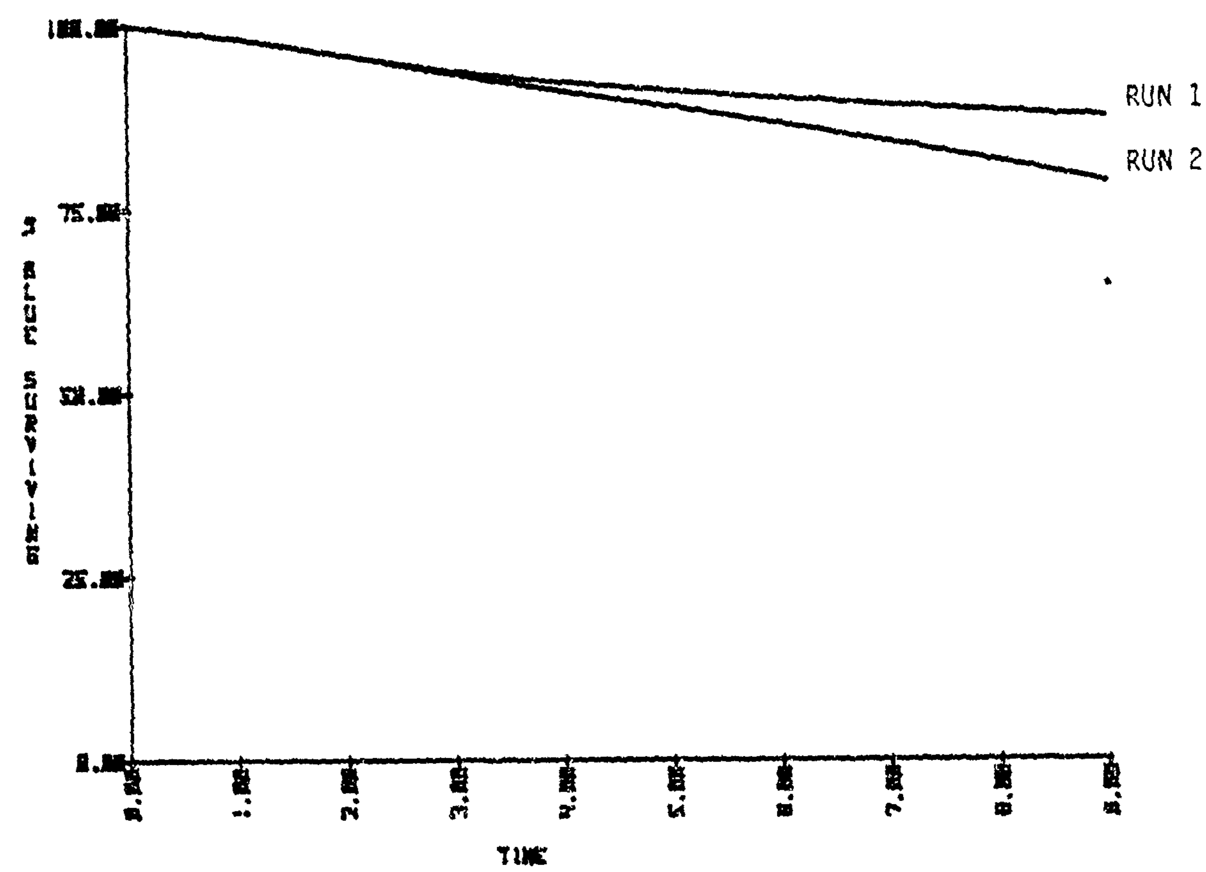

Figure 2-2. Percent Blue survivors, two battle runs

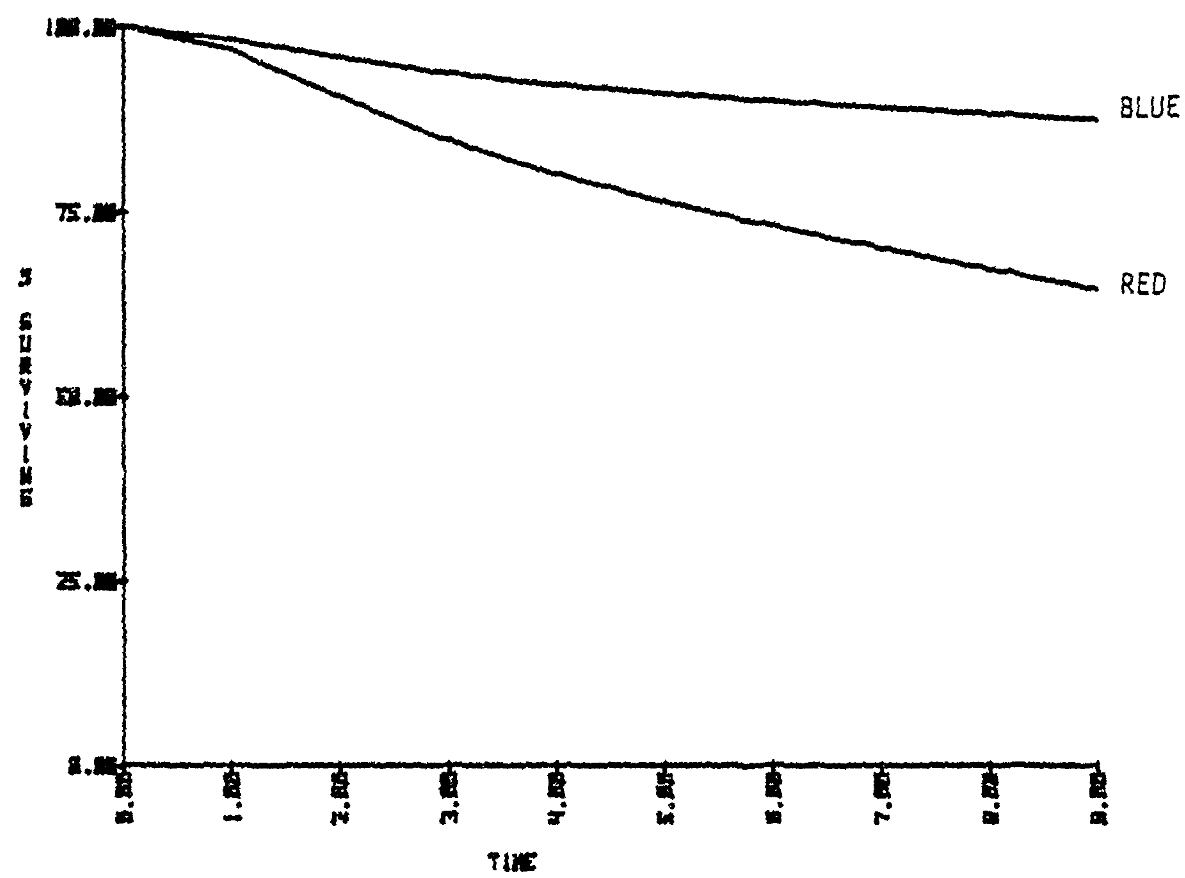

Figure 2-3. Percent Blue survivors and percent Red survivors, one battle run

their respective forces, and previous experience in war gaming is useful. In addition, another officer would be beneficial as an assistant to the commander whose forces are being varied during the study (normally the Blue force). This assistant could provide an additional area of expertise (e.g., artillery, aviation) of interest to a particular study, and he could serve as the commander's staff in surfacing tactical alternatives for the commander to consider.

(2) The game also requires a controller to ensure that the desired tactics are being followed, that the objectives of the study are being achieved, and that neither commander uses the perfect knowledge of the open game or learning experiences from the games to improper advantage.

(3) Finally, the game team needs one or two people to serve as statisticians/computer operators. Their primary responsibility is to prepare data for the model, run the computer, and translate output into effects on the units employed. They also serve as quality control by double checking the unit locations and strengths used by the Red and Blue commanders in their manual force files.

c. In preparation for the gaming, several supply items must be developed or obtained. Maps, overlays, unit stickers, and grease pencils for the map maneuvers are needed. The HP 9830 and software tape for the model must be made available. Forms must be developed for recording input data for the battles and for maintaining unit status information during the course of the game. A filing system for storing and retrieving these forms is also essential for use not only in the gaming but also in the postgame analysis.

d. Once gaming is initiated a specific sequence of activities is followed until a game termination point is reached. This sequence is as follows:

(1) The attacker defines his axes of advance, unit formation, and rates of movement. He specifies his artillery support, preparation fires, and reserve commitment condition.

(2) The controller approves the attacker's plan and establishes times of engagements.

(3) The defender defines battles in terms of opening ranges, elements of Blue units that will engage, and defender withdrawal condition.

(4) The controller approves the battles.

(5) The model is run, and the controller reviews the run for correctness. Records are made and files updated accordingly.

(6) The defender defines his new defensive positions, unit attachments, and unit movements.

(7) The controller approves the new defense plan and establishes completion time for unit movements. The process is repeated from step (1).

CHAPTER 3

REFERENCES

1. Davis, Reed E. Jr., COL, An HP-67 Combat Model, TP 8-77, July 1977. Directorate of Combat Operations Analysis, US Army Combined Arms Combat Development Activity, Fort Leavenworth, Kansas.

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3. TETAM Effectiveness Evaluation, Phase I, TM 2-73, November 1973. Combat Operations Analysis Directorate, US Army Combined Arms Combat Development Activity, Fort Leavenworth, Kansas.

4. Ignall, Edward J.; Kolesar, Peter; and Walker, Warren E., Using Simulation to Develop and Validate Analytic Models: Some Case Studies, Operations Research, Vol. 26, pp 237-253.

5. Begley, B. and Rowland, D. Analysis of Aspects of Tank Engagements on Exercise Chinese Eye III. United Kingdom.

APPENDIX A

GROUND COMBAT MODEL DATA REQUIREMENTS

A-1. PURPOSE. This appendix describes the data requirements of the Ground Combat Model. Terrain and scenario oriented data are discussed first, followed by weapon characteristics data. The data forms shown in this appendix are blank; however, the code listings in appendix B contain typical data.

A-2. TERRAIN AND SCENARIO ORIENTED DATA.

a. Terrain and scenario oriented data values are likely to change from battle to battle and from time increment to time increment as the battle situation changes. Figure A-1 shows the data elements required to initialize the battle. Figure A-2 shows the data elements that may be either predetermined or input after the model has run for some periods and the output has been investigated. In these figures, the letter "h" and a line number after an entry denotes that a value is currently hard-wired into the model and the line where the entry appears in the code. The other items are entered from the keyboard at the appropriate display.

b. The following comments refer to the data requirements shown on figure A-1.

(1) The start/stop battle time may be entered first in the context of the clock time of the battle and then in terms of number of minutes from 0 to end.

(2) The time step should be small (1 minute per period is generally used) since attritions are updated only at the end of the time period.

(3) Initial and maximum attack speeds, in units of km/min, are dependent on the terrain and vehicles being simulated.

(4) The line-of-sight terrain parameter currently in the model is derived from the TETAM field experiments (reference 3). The FASCAM parameter is derived from the FASCAM Cost and Operational Effectiveness Analysis (COEA) study.

(5) The target preferences and formation depths can be determined from doctrine or gamer decisions.

(6) When artillery preparation data are input, the control routine cycles through the artillery routine once before the first time period to simulate an artillery barrage before the battle starts.

(7) A total of 20 weapon types (both Blue and Red) may be designated as described in appendix B.

Terrain/Scenario: Data/Input:

Start/stop battle time (Battle clock time, xxxx/xxxx = number of minutes, 0/xx):

Time step (minutes):

Initial attack speed (km/min):

Maximum attack speed (km/min): h:4970

Terrain, LOS/FASCAM: h:1400, 1420, 5840

Target preferences (BRDM or BMP, TOW or Dragon, Copperhead):

Formation depths (km): h:1860, 2000

Artillery preparation (rounds by type and target):

Weapon type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial number																				
First time detect (h:1220)								0	0	0								0	0	0
Max time detect (h:1280, 1290, 3740-3790)																				
*Number of reinforcements																				
*Time of reinforcement																				

*Predetermined or input after game has started; also, attrition of FASCAM and artillery determined externally.

Figure A-1. Initial requirements, terrain/scenario oriented data

Each increment is _____ minutes.

Increment*	Percent of AH employed	Percent of AD available	Copperhead rds/min/GLLD	FASCAM Nr of fields | 0-bull 1-plow	Suppression 1-yes, 2-no
1					
2					
3					
4					
5					
. . .					

Increment*	Blue artillery - 1			Red artillery - 2		
	8	9	10	8	9	10
	Max Rd/min	Max Rd/min	Max Rd/min	Max Rd/min	Max Rd/min	Max Rd/min
	Tgt type 1 3 4 5 6	Tgt type 1 3 4 5 6	Tgt type 1 3 4 5 6	Tgt type 1 3 4 5 6	Tgt type 1 3 4 5 6	Tgt type 1 3 4 5 6
1						
2						
3						
4						
:						

*Predetermined or input after game has started.

Figure A-2. Requirements by iteration, terrain/scenario oriented data

(8) The "first time detect" value is the time when the model will allow a weapon type to start detecting and, hence, possibly firing. This time is determined by the gamer based on such considerations as terrain, weather, and approximate weapon range.

(9) The "max time detect" is the time at which the weapon type is expected to be operationally fully employed. This time is determined based on considerations such as terrain, advance rates, and formation depths.

(10) Number and time of reinforcements may be predetermined or input after the battle has progressed through a number of periods.

c. On figure A-2, the artillery entries are the maximum rounds per minute for the size unit being played (e.g., battery, regiment). Planned employment of Copperhead and FASCAM must be considered when this number is determined.

A-3. WEAPON ORIENTED DATA. Data that reflect weapon characteristics are shown at figures A-3 through A-6. These data are operationally oriented and in some cases may be the results of other simulations.

a. Artillery Weapon Data. In figure A-3, the lethal radius of artillery round versus target and the radius of coverage for weapon effects are fairly standard. Currently, artillery against helicopters is not modeled; thus, zeroes are place holders in data arrays. In this model the standard weapon dispersion and standard aim and location errors are combined into total range and deflection errors. These errors can be used directly in A(i) and B(i). The detection rates, maximum and degraded initially, are operational numbers obtainable from field data or judgmentally. The target radii I(j) depend on unit type and array being gamed.

b. Target Acquisition Data. The target acquisition rates (figure A-4) for direct fire, helicopters, and GLLD are operational data and are obtainable from field tests such as TETAM (reference 3) or Chinese Eye III (reference 5). These values, with suppression, control the rate of battle.

c. Engagement Data. The data to be entered in figure A-5 are operationally dependent, especially the rates. These rates are the sustainable maximum rates of targets per minute. Due to the mathematical reasons discussed in appendix B, the values B(i) for initial battle ranges must be neither equal to nor one-half of the opposing tank open fire range. Also, as discussed in appendix B, the values of D(i,j) need not be pure probability of kill given hit but may also account for the fact that different target types have different hit probabilities against them while only one single shot hit probability is being computed.

d. Attack Helicopter, Air Defense, Copperhead, and FASCAM. The data for these weapons are determined from the results of other models. For the attack helicopter and air defense, modified results from the Individual Engagement Model/Sortie Effectiveness Model (IEM/SEM) are being used. IEM/SEM has been used to support several studies at CACDA. Since the Ground Combat Model

<table>
<tr><th>Data element</th><th>Blue 8
1</th><th>Blue 9
2</th><th>Blue 10
3</th><th>Red 8
4</th><th>Red 9
5</th><th>Red 10
6</th></tr>
<tr><td>Lethal radius of weapon vs target: 1
2
C(i,j) meters 3
(3540-3590) 4
5
6</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Radius of coverage
D(i,j) meters
(3540-3590)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Standard weapon dispersion
S(i) meters
(4180)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Standard aim and location error
B(i) meters
(4180)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Maximum detection rate
C(i,j) tgts/min
(3740-3790)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Initial detection factor
G(i,j) percent of max detection rate
(3740-3790)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Individual/group target radius
I(j) meters
(4220)</td><td colspan="3">Blue</td><td colspan="3">Red</td></tr>
<tr><td>1
2
3</td><td colspan="2">4
5
6</td><td colspan="2">11
12
13</td><td>14
15
16</td></tr>
</table>

Figure A-3. Artillery weapon data

Weapon	1 2 3 4	5 6 7 8	9 10 11 12	13 14 15 16
Maximum detection rate C(i,1) tgts/min (1280-1290)				
Initial detection rate B(i) tgts/min (1500)				

Figure A-4. Target acquisition data (direct fire, attack helicopter, Copperhead)

	Blue	Red
Individual tank engagement rate A(I1) tgts/min (1650, 1660, 1820, 1830)		
Effective open fire range B(I1) km (1700, 1710, 1840, 1850)		
Opposing tank open fire range I9 km (2540, 2560) (Relate to 1700, 1710, 1840, 1850)		

Figure A-5a. Engagement data, tanks (continued next page)

	4	5	14	15	16	GLLD
Fitting parameters for ith ATGM A(i) (1650-1740) B(i)						NA NA
Suppression parameters for ith system (2140) B(i)						

Figure A-5b. Engagement data, ATGM

		1	4	5	11	14	15	16
Initial battle range B(i) (3140) Relate to 1700, 1710, 1840, 1850, 2540, 2560								
Fitting parameter for single shot hit probabilities A(i) (2260-2280) B(i)								
Basic load T(i) (120)								
Probability of kill given hit P_{ij} (K/H) = D(i,j) (3200-3320)	1 4 5 6							

Figure A-5c. Engagement data, miscellaneous

Single shot kill probabilities (SSKP)	BLUE	RED
Attack helicopter A(i) (5200, 5210)		
Air defense A(i) (5470, 5480)		
Copperhead S7 (5660)		
Kills per target per FASCAM minefield		
Bull (5860)		
Plow (5880)		

Figure A-6. Attack helicopter, air defense, Copperhead, and FASCAM weapon data

computes line of sight and number of targets acquired for the attack helicopters, the IEM/SEM version having probability of line of sight and acquisition equal to one should be used. Copperhead effectiveness was determined from studies run at Fort Sill, OK. The FASCAM COEA completed at CACDA provided data on the relationship between kills and number of standard 300m x 300m, 90-mine, minefields.

APPENDIX B

DETAILED DESCRIPTION OF GROUND COMBAT MODEL ROUTINES

B-1. PURPOSE. This appendix details the methodology and interrelations of the computer routines that make up the Ground Combat Model.

B-2. WEAPON LISTS AND DATA FORMAT. The numbers of weapons of each type are stored in the array N(i,j). That array, the cumulative killer-victim array K(i,j), suppressible target losses per period array O(i), weapon load arrays R(i) and T(i), and the output array X(i,j), as shown in figure B-1, are the only arrays with the same definition throughout the model. The X(i,j) array is further explained in appendix C. Figure B-1 also codes the weapon order so that the computer can keep track of weapon types and data. For example, N(4,2) is the number of Blue TOWs surviving at that battle time, whereas N(1,3) is the total number of Red tanks committed to the battle by that battle time. (The program may be stopped at any time, the N(i,j) and K(i,j) arrays printed, and then the program restarted.) Arrays of two dimensions for weapon characteristics use codes 1 through 10 in the first coordinate for weapon type, 1 for Blue and 2 for Red in the second coordinate. Vector arrays use codes 1 through 10 for Blue weapons and 11 on for Red weapons. Figure B-2 contains the major variables that are the same throughout the model. Arrays and variables had to be reused for conservation of memory and restrictions on the number of variables allowed in the HP 9830.

B-3. MODIFICATIONS. This paragraph discusses some possible modifications to the code included in this appendix. Extensive modifications will be difficult due to the memory restrictions of the HP 9830. This code uses all but about 200 words of about 7,900 words possible. In applications with certain inputs known and constant or other particular information given, modifications probably can be made to reduce memory requirements or running time. This was done in the MANFIST study.

a. The present code is limited to 30 iterations, and the output is stored in a common block X(31,7) as noted in line 5, paragraph B-4b below. Additional iterations will require either more space or a careful restart with proper setting of array N, battle range R1, battle time T0, current attack rate V5, and killer-victim array K.

b. Modeling the application of artillery against helicopters could be done with care. Other aspects of artillery employment, such as against multiple targets, are mentioned in paragraph B-12; and further modeling could be done.

c. Modeling of air-to-air attack helicopter engagements and employment of selected air defense artillery in a direct fire mode could probably be accomplished with care. Further modifications to the air defense routine are mentioned in paragraph B-17.

N(10,4) (i,j)
i = 1-10

N(i,1)	Number Blue committed by type
N(i,2)	Number Blue surviving
N(i,3)	Number Red committed by type
N(i,4)	Number Red surviving

Weapons order

Code	Blue	Red
1	Tank	Tank
2	Helicopter	Helicopter
3	Air defense	Air defense
4	TOW	BRDM
5	Dragon	BMP/Sagger
6	Copperhead	BMP/73mm
7	FASCAM	blank
8	Artillery type 1	Artillery type 1
9	Artillery type 2	Artillery type 2
10	Artillery type 3	Artillery type 3

K(20,6) (i,j)

i = 1-10 Number ith Blue weapon kills of jth Red weapon
i = 11-20 Number (i-10)th Red weapon kills of jth Blue weapon
j = 1-6

O(8)

i = 1-3 for Blue, 4-6 for Red, 7 for Blue tank, 8 for Red tank

Soft target losses in previous time period increment for suppression computations.

R(16) and T(16) Selected weapon loads

X(31,7) (i,j)

j = 1	Time	j = 5	Attack rate
j = 2	Blue strength	j = 6	Blue committed
j = 3	Red strength	j = 7	Red committed
j = 4	Range		

Figure B-1. Major arrays in Ground Combat Model

Variable Name	Definition
I0	Code for weapon type being processed, 1-10
I1	Code for weapon type being processed, 1-20
J0	Current side, 1 = Blue, 2 = Red
S0	1 = suppression
T0	Current battle time
T1	Time step
V0	Initial attack speed
R1	Current battle range
R2	Current range step
B1	Total committed Blue strength
D1	Total committed Red strength
B4	Current Blue strength
D4	Current Red strength
B5	Cumulative Blue losses
D5	Cumulative Red losses
P3	Blue preference for BRDM over BMP
P4	Red preference for TOW over Dragon/GLLD

Figure B-2. Major variables in Ground Combat Model

d. The model has been changed to allow simulation of Blue attacking and Red defending. In addition to a major revamping of data, minor changes in the engagement rate subroutine branching and rate of advance computation were made.

e. The domain values for range R1 may be shifted linearly by R2/2, half the range step from the previous period, in the tank engagement rate routines. This would speed up the tank battle at the longer ranges by reflecting somewhat the distribution of vehicles about the average range R1 and the dynamics of the model.

B-4. CONTROL.

a. <u>Purpose</u>. This routine initializes each computer run and controls the order in which the weapon routines are accessed.

b. <u>Control Subroutine Listing</u>.

```
10 COM Y[31,7]
20 DIM N[10,4],A[16],B[16],C[16,6],D[16,6],K[20,6],T[16]
30 DIM G[7,3],H[6],J[5],L[3],M[3],P[6],Q[16],S[6,2]
40 FIXED 2
50 MAT Y=ZER
60 MAT O=ZER
70 MAT K=ZER
80 FOR I9=1 TO 16
90 READ T[I9]
100 R[I9]=T[I9]
110 NEXT I9
120 DATA 55,0,0,12,4,3,0,0,0,0,-0,0,0,4,4,25
130 PRINT "INIT BL FORCE(1-10)"
140 INPUT N[1,1],N[2,1],N[3,1],N[4,1],N[5,1],N[6,1],N[7,1],N[8,1],N[9,1],N[10,1]
150 PRINT "INIT RE FORCE(1-10)"
160 INPUT N[1,3],N[2,3],N[3,3],N[4,3],N[5,3],N[6,3],N[7,3],N[8,3],N[9,3],N[10,3]
170 FOR I9=1 TO 10
180 N[I9,2]=N[I9,1]
190 N[I9,4]=N[I9,3]
200 NEXT I9
210 PRINT "INIT BTL RNG"
220 INPUT R1
230 PRINT "INIT ATK RATE"
240 INPUT V0
250 PRINT "TIME STEP"
260 INPUT T1
270 T0=0
280 M1=0
290 GOSUB 6040
300 GOSUB 4960
```

```
310 X[1,1]=0
320 X[1,2]=B1*100
330 X[1,3]=(D1-325)*100
340 X[1,4]=R1*1000
350 X[1,5]=V0*1000
360 X[1,6]=B1*100
370 X[1,7]=(D1-325)*100
380 PRINT "1-SUP,0-NOT"
390 INPUT S0
400 PRINT "PRE BRDM V BMP,TOW V DP"
410 INPUT P3,P4
420 Z0=0
430 Z1=0
440 Z0=Z0+1
450 PRINT
460 IF Z1=1 THEN 490
470 PRINT "ARTY PREP"
480 GOTO 500
490 PRINT "TIME STEP":Z0
500 GOSUB 5450
510 PRINT "[illegible] #,1-BL/2- E/(0,0)-NONE"
520 INPUT I0,J0
530 IF I0=0 AND Z1=1 THEN 330
540 IF I0=0 THEN 570
550 GOSUB 3440
560 IF Z1=1 THEN 510
570 PRINT "1-PREP OVER, 0-NOT"
580 INPUT Z1
590 IF Z1<0.5 THEN 510
600 PRINT "PREP OVER"
610 GOSUB 5130
620 GOSUB 4960
630 GOTO 510
640 REM
650 I0=1
660 FOR J0=1 TO 2
670 GOSUB 3070
680 NEXT J0
690 FOR I0=4 TO 5
700 FOR J0=1 TO 2
710 GOSUB 3070
720 NEXT J0
730 NEXT I0
740 I0=6
750 J0=2
760 GOSUB 3070
770 I0=2
780 J0=1
790 GOSUB 5120
```

```
800 I0=3
810 J0=2
820 GOSUB 5400
830 I0=2
840 J0=2
850 GOSUB 5120
860 I0=3
870 J0=1
880 GOSUB 5400
890 J0=1
900 I0=7
910 GOSUB 5790
920 I0=6
930 GOSUB 5530
940 GOSUB 6130
950 GOSUB 4960
960 R1=R1-R2
970 T0=T0+T1
980 X[Z0+1,1]=T0*100
990 X[Z0+1,2]=?4*100
1000 X[Z0+1,3]=(D4-325)*100
1010 X[Z0+1,4]=?1*1000
1020 X[Z0+1,5]=V5*1000
1030 X[Z0+1,6]=?1*100
1040 X[Z0+1,7]=(D1-325)*100
1050 GOSUB 4770
1060 IF R1>0 THEN 1090
1070 PRINT "OVERRUN"
1080 GOTO 1160
1090 IF V5>0.001 THEN 1110
1100 PRINT "SLOWED"
1110 DISP "1=YES";
1120 INPUT I9
1130 IF I9#1 THEN 440
1140 GOSUB 4250
1150 GOTO 440
1160 END
```

c. Data Variables.

T0	Battle time (initially zero and then incremented by time step)
Z0	Iteration counter
Z1	Artillery preparation counter
I0	Weapon type, 1-10
J0	1 = Blue, 2 = Red
T(i)	Weapon basic loads, 1-20

d. Defined and Computed Variables.

N(i,j)	Number of weapons by type, by Red or Blue, and by committed or remaining (see appendix A).
X(i,j)	Battle results saved for future graphing of measures of effectiveness (see appendix C).
R1	Battle range (initial)
V0	Initial attack speed
S0	1 = suppression played
T1	Time step per iteration
I9	1 = Commit reserves
R(i)	Current weapon load, 1-20

e. Modeling. The function of this routine is bookkeeping and control. Figure 2-1 shows the order in which the weapon routines are accessed. Figure B-3 shows the subroutine call relationships of control as well as the other model subroutines.

B-5. TARGET ACQUISITION.

a. Purpose. The purpose of this subroutine is to compute the number of targets detected by the direct fire weapons such as tanks and TOWs as well as by the attack helicopters and the GLLDs of the Copperhead. The routine considers the battle time and the scenario-determined involvement of the weapon in the battle to compute the detection rate of each weapon type. The only weapons detectable are opposing live ones of types 1 through 6.

Caller	Control	Target acquisition	Engage rate-ATGM	Engage rate-attack tank	Engage rate-defend tank	Suppression	Single shot hit prob	Engagement	Allocation	Ground attrition	Artillery	Reserve commitment	Battle status	Advance rate	Attack helicopters	Air defense	Copperhead	FASCAM	Battle cumulatives	Initialization	Update of forces
Control										X	X	X	X	X	X	X	X	X	X	X	X
Engagement rates						X															
Engagement		X	X	X	X		X														
Ground attrition								X	X												
Reserve commitment													X							X	
Battle status																			X		
Advance rate																			X		
Attack helicopters		X																			
Copperhead		X				X															

Figure B-3. Subroutine call relationships

b. <u>Target Acquisition Subroutine Listing</u>.

```
1170 REM ACQ
1180 RESTORE 1220
1190 FOR I9=1 TO 16
1200 READ A[I9]
1210 NEXT I9
1220 DATA 0,0,0,0,4,0,3,0,0,0,0,0,0,0,0,5
1230 T4=0
1240 IF T0<A[I1] THEN 1440
1250 FOR I9=1 TO 16
1260 READ C[I9,1],C[I9,2]
1270 NEXT I9
1280 DATA 0.4,2,0.25,2,1,2,0.25,2,0.3,6,0.25,5,1,2,1,2,1,2,1,2
1290 DATA 0.4,2,0.25,2,1,2,0.25,2,0.1,2,0.1,7
1300 I7=FN7(0)
1310 L7=LOG(T0-A[I1]+C[I1,4])/C[I1,3]
1320 IF L7 <= C[I1,1] THEN 1340
1330 L7=C[I1,1]
1340 P7=1-EXP(-L7*T1)
1350 J9=6-2*J0
1360 N7=N[1,J9]
1370 FOR I9=3 TO 6
1380 N7=N7+N[I9,J9]
1390 NEXT I9
1400 I9=0.56*(1+P1)*EXP(-0.34*P1)
1410 IF I0#2 AND I0#3 THEN 1430
1420 I9=1.06*(0.57+0.1*P1)*EXP(-0.1*P1)
1430 T4=N7*(1-(1-I9*P7)^N[I0,2*J0])
1440 RETURN
1450 DEF FNZ(I)
1460 RESTORE 1500
1470 FOR I9=1 TO 16
1480 READ P[I9]
1490 NEXT I9
1500 DATA 0.1,0.1,0,0.1,0.1,0.1,0,0,0,0,0.1,0.1,0.1,0.1,0.05,0.05
1510 C[I1,3]=1
1520 J9=0
1530 J9=J9+1
1540 I9=C[I1,3]
1550 C[I1,3]=LOG(C[I1,2]-A[I1]+EXP(P[I1]*C[I1,3]))/C[I1,1]
1560 IF ABS(I9-C[I1,3])<0.001 THEN 1600
1570 IF J9>20 THEN 1590
1580 GOTO 1530
1590 PRINT "NO CONV"
1600 IF C[I1,3]>0 THEN 1620
1610 C[I1,3]=0
1620 C[I1,4]=EXP(C[I1,3]*P[I1])
1630 RETURN 0
```

c. Data Variables.

A(i) Time of first detection

C(i,1) Maximum detection rate

C(i,2) Battle time when maximum detection rate obtained

B(i) Detection rate initially; i.e., at A(i)

d. Defined and Computed Variables.

L7 Detection rate for weapon I1 at battle time T0

P7 Probability of detection by weapon I1 during time interval from T0 to T0+T1

N7 Number of potential targets alive on the opposing side at time T0

J9 2 = Opposing side Blue, 4 = Opposing side Red

I9 Probability of instantaneous line of sight

T4 Targets acquired by weapon system I1

$\left.\begin{array}{l} C(i,3) \\ C(i,4) \end{array}\right\}$ Parameters in determining detection rate

e. Modeling.

(1) The probability of instantaneous line of sight (LOS) at range R is computed by a three-parameter terrain fit (a,b,c in the code at lines 1400-1420):

$$I9 = P_{LOS\ (R\ )} = a(b + c\ R1)e^{-\ c\ R1}$$

(2) The probability of detection at T0 within T1 minutes is given by:

$$P7 = P_d\ (T1) = 1 - e^{-\ L7 \cdot T1}$$

where L7, the detection rate in targets per minute, is determined by a log curve fit to initial and maximum detection rates. The parameters C(i,3) and C(i,4) are determined by iteratively solving the equations:

$$C(i,4) = e^{C(i,3)B(i)}$$

$$C(i,3) = \frac{\log(C(i,2)-A(i)+C(i,4))}{C(i,1)}$$

in the function Z. Then L7 is determined by:

$$L7^* = \begin{cases} 0 & \text{if } T0 < A(i) \\ \log \dfrac{(T0-A(i)+C(i,4))}{C(i,3)} & \text{if } T0 \geq A(i) \end{cases}$$

$$L7 = \min\,(L7^*, C(i,1))$$

(3) The total number of targets acquired by a direct fire weapon system (including attack helicopters and Copperheads) is determined from the line-of-sight probability, time probability of detection, and the number of potential targets:

$$T4 = N7 \cdot (1-(1-I9 \cdot P7)^{N(I0,2 \cdot J0)})$$

T4, the number of targets acquired, is the variable required by the calling routines.

f. Notes.

(1) It is assumed that only attack helicopters (and possibly air defense in further modifications) have line-of-sight parameters different from those of the direct fire weapons.

(2) The values $C(i,2)-A(i)+C(i,4)$ and $T0-A(i)+C(i,4)$ must be greater than one. This will be the case if $C(i,2) > A(i)+1$; i.e., at least one minute elapses between detection initiation and time at which maximum detection rate is obtained. In the convergence of the $C(i,3)$ if a change of less than .001 does not occur within 20 iterations, then a "no convergence" message is printed. Mathematically, with the restriction on $C(i,2)-A(i)+C(i,4)$, convergence must occur eventually.

(3) The probability of instantaneous LOS is a statistic measured as a function of range between two random locations in a given terrain. Thus, the effects of LOS duration must be taken into account in determining operational engagement rates, paragraph B-6.

B-6. ENGAGEMENT RATE SUBROUTINES.

a. Purpose. These three subroutines compute the direct fire weapon operational engagement rates in targets per minute as functions of range. The ATGM rates decrease linearly as a function of range. The attacking tank rates decrease exponentially as a function of range dependent on effective open fire range and the formation depth, whereas the defending tank rates decrease linearly.

b. <u>Engagement Rates Subroutines Listing.</u>

```
1640 REM-ENG
1650 A[4]=0.3
1660 A[5]=0.2
1670 A[14]=0.25
1680 A[15]=0.15
1690 A[16]=0.15
1700 B[4]=0.04
1710 B[5]=0.05
1720 B[14]=0.05
1730 B[15]=0.05
1740 B[16]=0.05
1750 E4=A[I1]-B[I1]*R1
1760 IF E4>0 THEN 1780
1770 E4=0
1780 GOSUB 2090
1790 E4=E4-E4*S4
1800 RETURN
1810 REM ENG AT
1820 A[1]=0.5
1830 A[11]=0.25
1840 B[1]=2.8
1850 B[11]=2.6
1860 J9=0.75
1870 E4=0
1880 IF R1>B[I1] THEN 1920
1890 E4=A[I1]
1900 IF R1<(B[I1]-J9) THEN 1920
1910 E4=EXP(LOG(A[I1]+1)*(B[I1]-R1)
1920 GOSUB 2090
1930 E4=E4-E4*S4
1940 RETURN
1950 REM ENG OF
1960 A[1]=0.5
1970 A[11]=0.25
1980 B[1]=2.8
1990 B[11]=2.6
2000 J9=0.3
2010 E4=0
2020 IF R1>B[I1] THEN 2060
2030 E4=A[I1]
2040 IF R1<(B[I1]-J9) THEN 2060
2050 E4=A[I1]*(B[I1]-R1)/J9
2060 GOSUB 2090
2070 E4=E4-E4*S4
2080 RETURN
```

c. ATGM.

(1) Data variables.

$\left.\begin{matrix} A(i) \\ B(i) \end{matrix}\right\}$ Positive fitting parameters

(2) Defined and computed variables.

E4 Engagement rate in targets per minute

(3) Modeling. The unsuppressed engagement rate for ATGMs is simply $E4 = A(i)-B(i) \cdot R1$. If suppression is being played, the suppression variable S4 is utilized by multiplying E4 by 1-S4 (see paragraph B-7). E4, the number of targets per minute engaged per firing weapon, is the variable required by the calling routine.

d. Attacking Tanks.

(1) Data variables.

A(i) Individual tank maximum operational engagement rate

B(i) Effective open fire range for the attacking tank

J9 Formation depth for attacking tanks

(2) Defined and computed variables.

E4 Engagement rate in targets per minute

(3) Modeling. The engagement rate for targets per minute by attacking tanks is:

$$E4 = \begin{cases} 0 & \text{if } R1 > B(i) \\ e^{\left[\log\,(A(i)\,+\,1)\right] \cdot \left[\frac{B(i)-R1}{J9}\right]} - 1 & \text{if } B(i)-J9 < R1 < B(i) \\ A(i) & \text{if } R1 < B(i)-J9 \end{cases}$$

E4 is the variable required by the calling routine.

e. Defending tanks.

(1) Data variables.

A(i) Individual tank maximum operational engagement rate

B(i) Effective open fire range for the defending tank

J9 Formation depth for defending tanks

(2) Defined and computed variables.

E4 Engagement rate in targets per minute

(3) Modeling. The engagement rate for targets per minute by defending tanks is:

$$E4 = \begin{cases} 0 & \text{if } R1 > B(i) \\ A(i) \cdot \dfrac{(B(i)-R1)}{J9} & \text{if } B(i)-J9 \leq R1 \leq B(i) \\ A(i) & \text{if } R1 < B(i)-J9 \end{cases}$$

f. Notes.

(1) In a small unit battle, E4 may well be constrained by the number of available rounds or missiles; i.e., stowed load, rather than by weapon system/crew capabilities. The input data should reflect these considerations.

(2) The engagement rate by attacking tanks given by the formula in paragraph d(3) above is suited more for a probing formation with lead elements out front. A formula more appropriate for the vehicles bunched at the front of the attack for ranges R1 of $B(i)-J9 < R1 < B(i)$ may be:

$$E4 = A(i) \cdot \log (1 + B(i)-R1)/\log (1 + J9)$$

(3) As the battle closes, the defender's tanks are deployed in some depth, and the attacker's tanks are part of a selected attack formation. The formation depth, or deployed depth, term in the engagement rate calculations accounts for the nonsimultaneous entry of surviving tanks into the battle. Suppression is used to reduce the effective number of firers by reducing the engagement rate.

B-7. SUPPRESSION.

a. Purpose. This subroutine represents the Litton suppression formula (reference 2) and is accessed by option on each iteration. The percent of suppression depends each time step on an input "hero factor" and the fractional losses to the system during the previous time step. (No suppression is possible during the first time step.)

b. Suppression Subroutine Listing.

```
2090 REM SUP
2100 S4=0
2110 IF S0=0 THEN 2220
2120 RESTORE 2140
2130 READ B[1],B[4],B[5],B[6],B[11],B[14],B[15],B[16]
2140 DATA 0.2,0.[illegible],0.6,0.6,0.2,0.6,0.6,0.6
2150 A[I1]=O[6+J0]/N[1,2*J0]
2160 IF I0=1 THEN 2180
2170 A[I1]=O[I0-6+3*J0]/N[I0,2*J0]
2180 IF A[I1]<0.001 THEN 2220
2190 S4=10*EXP((-0.04)*(1-A[I1])^2/(B[I1]*A[I1]))-5
2200 S4=EXP(S4)
2210 S4=S4/(S4+1)
2220 RETURN
```

c. Data Variables.

B(i) The beta of the Litton model, also called the "hero factor."

d. Defined and Computed Variables.

A(i) Fractional losses to system I1 during previous time step (computed from losses O(i) in previous time step)

S4 Suppressed fraction for weapon I1.

e. Modeling. The Litton documentation (reference 2) contains an equation that gives the fraction of suppression as a function of losses and a human factor. A value of 1 for B(i) is used to represent the "average" soldier, with higher values for more easily suppressed individuals and lower values for individuals more difficult to suppress. The equation is:

$$S4^* = \left[10 \cdot e^{\left(- \frac{.04(1-A(i))^2}{B(i) \cdot A(i)}\right)} \right] - 5$$

$$S4 = \frac{e^{S4^*}}{e^{S4^*} + 1}$$

S4, the suppressed fraction, is the variable required by the calling routines.

B-8. SINGLE SHOT HIT PROBABILITY.

a. Purpose. In this subroutine the single shot hit probability (SSHP) by direct fire weapons is computed by two different formulas, which depend on whether the weapon is a tank or not. This single shot hit probability is a function of battle ranges.

b. SSHP Subroutine Listing.

```
2230 REM--SSHP
2240 RESTORE 2260
2250 READ A[1],A[4],A[5],A[11],A[14],A[15],A[16]
2260 DATA -0.05,0.84,0.7,-0.06,0.35,0.75,-0.1
2270 READ B[1],B[4],B[5],B[11],B[14],B[15],B[16]
2280 DATA -0.11,0.09,0,-0.13,0.1,0.1,-0.25
2290 H4=1+A[I1]*R1+B[I1]*R1*R1
2300 IF I0=1 THEN 2320
2310 H4=A[I1]+B[I1]*LOG(R1)
2320 IF H4>0 THEN 2340
2330 H =0
2340 IF H4<1 THEN 2360
2350 H4=1
2360 RETURN
```

c. Data Variables.

A(i), B(i) Fitting parameters

d. Defined and Computed Variables.

H4 Single shot hit probability

e. <u>Modeling</u>.

(1) Tanks. H4 by tanks is given by:

$$H4 = 1 + A(i) \cdot R1 + B(i) \cdot R1^2$$

(2) Other direct fire weapons. H4 in this case is given by:

$$H4 = A(i) + B(i) \cdot \log (R1)$$

H4, the SSHP, is the variable required by the calling routine.

f. <u>Notes</u>. The single shot hit probability computed here is independent of target. The effects of target size, activity, posture, etc. must be considered here in combination with the ground attrition routine and the input variable D(i,j), paragraph B-10.

B-9. ENGAGEMENT ROUTINE.

a. <u>Purpose</u>. This subroutine determines the total number of hits by all weapons of a given type and total number of rounds fired by each weapon of a given type each time the subroutine is entered.

b. <u>Engagement Subroutine Listing</u>.

```
2370 REM ENG
2380 GOSUB 1170
2390 H5=H6=0
2400 IF T4=0 THEN 2520
2410 GOSUB 2230
2420 IF H4=0 THEN 2520
2430 IF I0=4 OR I0=5 OR (I0=6 AND J0=2) THEN 2490
2440 IF I1=11 THEN 2470
2450 GOSUB 1950
2460 GOTO 2500
2470 GOSUB 1610
2480 GOTO 2500
2490 GOSUB 1640
2500 H6=E4*T1
2510 H5=H6*H4*N[I0,2*J]
2520 RETURN
```

c. Data Variables. The routine calls up to three other subroutines to determine its required data.

d. Defined and Computed Variables.

H5 Total number of hits against all targets acquired and engaged by all weapons of a given type each time period

H6 Total number of rounds fired by typical weapon of a given type each time period.

e. Modeling.

(1) The total number of rounds fired H6 by a typical weapon in time period T0 to T0 + T1 is determined from the number of targets acquired T4, and the engagement rate E4, by:

$$H6 = E4 \cdot T1$$

(2) The total number hits H5 in time period T0 to T0 + T1 is determined from the number of rounds fired per weapon of a given type H6, T4, the engagement rate E4, the SSHP H4, and the number of firers N(I0,2·J0) by:

$$H5 = H6 \cdot H4 \cdot N(I0, 2 \cdot J0).$$

Both H5 and H6 are variables required by the calling routine.

B-10. DIRECT FIRE ALLOCATION OF FIRES.

a. Purpose. This subroutine determines how the direct fire weapons allocate the fires over the types of targets. Two principal factors that influence the allocation of fires are the firer's preference for targets by type and the instantaneous rate of cued detections for particular type targets. Initially, it will be assumed that the firer will satisfy his preferences within the constraint imposed by the number of cued detections; i.e., the method emphasizes the tank targets within the opposing tank open fire range and the softer targets beyond the opposing tank open fire range.

b. Allocation Subroutine Listing.

```
2530 REM ALLO
2540 I9=2.5
2550 IF J0=1 THEN 2570
2560 I9=3
2570 RESTORE 2610
2580 FOR I7=1 TO 16
2590 READ P(I7)
2600 NEXT I7
```

```
2610 DATA 3.1,0,0,2.9,1.3.2,0,0,0,0,2.6,0,0,3.1,2.6,1.6
2620 A4=0
2630 J9=B[I1]
2640 I8=6-2*J0
2650 IF N[1,I8]=0 THEN 2860
2660 IF N[4,I8]+N[5,I8]+N[6,I8]=0 THEN 2860
2670 A[1]=(N[4,4]+N[5,4]+N[6,4])/D4
2680 A[2]=(N[4,2]+N[5,2]+N[6,2])/D4
2690 G[1,1]=G[2,1]=I9^3
2700 G[3,1]=J9^3
2710 G[1,2]=2*I9^2
2720 G[2,2]=I9^2
2730 G[3,2]=J9^2
2740 G[1,3]=4*I9
2750 G[2,3]=I9
2760 G[3,3]=J9
2770 MAT G=INV(G)
2780 C[1,J0]=1-A[J0]/2
2790 C[2,J0]=2/3-A[J0]/3
2800 L[1]=8*C[1,J0]-8
2810 L[2]=-A[J0]
2820 L[3]=C[2,J0]-1
2830 MAT M=G*L
2840 A4=M[1]*R1^3+M[2]*R1*R1+M[3]*R1+1
2850 IF A4>0 THEN 2870
2860 A4=0
2870 IF A4<1 THEN 2890
2880 A4=1
2890 IF J6=1 THEN 3060
2900 I7=P3
2910 IF J0=1 THEN 2930
2920 I7=P4
2930 IF N[4,I8]>0 THEN 2960
2940 I7=0
2950 GOTO 2980
2960 IF N[5,I8]+N[6,I8]>0 THEN 2980
2970 I7=1
2980 IF J6=5 OR J6=6 THEN 3010
2990 A4=(1-A4)*I7
3000 GOTO 3060
3010 IF N[5,I8]+N[6,I8]>0 THEN 3040
3020 A4=0
3030 GOTO 3060
3040 I9=N[J6,I8]/(N[5,I8]+N[6,I8])
3050 A4=(1-A4)*(1-I7)*I9
3060 RETURN
```

c. Data Variables.

I9 Opposing tank open fire range (top half)

B(i) Initial battle range of firing weapon 1-20.

d. Defined and Computed Variables.

J9 B(i) above

I8 2 if J0 = 2, 4 if J0 = 1

A4 Fraction of fires by firing weapon type to target type under consideration

A(j) Ratio of soft possible targets to total possible targets

G(i,j) Coefficients of system of equations to determine allocation

L(i) Right hand side of system of equations

C(i,j) Tactical preferences on cued versus random detections

I7 Preferences among two soft target types (lower half)

I9 Ratio of possible targets among two soft target types (lower half).

e. Modeling. This routine first determines the allocation of fire by the firing weapon type against opposing hard targets. It is accomplished by fitting a cubic curve to four distinct points giving the allocation A4* as a function of range. The four points are:

A4* = 1 at battle range R1 = 0

A4* = 1-A(J0) at I9, the opposing tank open fire range

A4* = C(1,J0) at I9/2

A4* = C(2,J0) at B(i), the initial battle range of the firing weapon.

The equation is:

$$A4^* = M(1) \cdot R1^3 + M(2) \cdot R1^2 + M(3) \cdot R1 + 1.$$

The simplified system of equations solved to determine the coefficients M(i) is:

$$G(i,j)\ M(i) = L(i).$$

If the target is not a tank, as determined from the value of J6 passed from the calling ground attrition routine, then A4 is (1-A4) times the preference factor of TOW over Dragon and GLLDs (or vice versa) or BRDMs over BMPs (or vice versa) times the ratio of Dragons or GLLDs to total if needed. A4 is the variable required by the calling routine.

f. Notes.

(1) Care must be taken that no B(i) equals either an opposing tank's open fire range or one-half of an opposing tank's open fire range. If so, the matrix G is singular and the M's are impossible to solve.

(2) Note that $C(2,J0) \leq 1-A(J0) \leq C(1,J0) \leq 1$ should be true.

(3) Currently the preference of C(1,J0) at one-half the opposing tank's open fire range is the average of one and the ratio of hard to total targets. The preference of C(2,J0) at the initial battle range is two-thirds the ratio of hard to total targets. These values, which were chosen after consideration of desired preferences and detection/acquisition equipment discriminability, can be changed easily.

B-11. GROUND ATTRITION.

a. Purpose. This subroutine computes the cumulative killer-victim table entries for the direct fire firing weapons; i.e., tank, TOW, Dragon, BRDM, and BMP. To accomplish this, the subroutine calls several other routines to obtain hits and allocation of fires (see figure B-3). The remaining load per weapon is also checked.

b. Ground Attrition Subroutine Listing.

```
3070 REM ATT
3080 IF N[I0,2*J0] <= 0 THEN 3430
3090 I1=30+10*(J0-1)
3100 RESTORE 3140
3110 FOR I7=1 TO 16
3120 READ B[I7]
3130 NEXT I7
3140 DATA 3.1,0,0,2.9,1.3,2.0,0.0,0,2.6,0,0,3.1,2.8,1.6
3150 IF B[I1]<R1 THEN 3430
3160 GOSUB 2370
3170 IF H5=0 THEN 3430
3180 RESTORE 3200
3190 READ D[1,1],D[1,4],D[1,5],D[1,6]
3200 DATA 0.9,0.65,0.6,0.6
3210 READ D[4,1],D[4,4],D[4,5],D[4,6]
3220 DATA 0.7,0.85,0.85,0.85
3230 READ D[5,1],D[5,4],D[5,5],D[5,6]
3240 DATA 0.8,0.9,0.9,0.9
3250 READ D[11,1],D[11,4],D[11,5],D[11,6]
3260 DATA 0.5,0.3,0.1,0.1
3270 READ D[14,1],D[14,4],D[14,5],D[14,6]
```

```
3280 DATA 0.4,0.7,0.1,0
3290 READ D[15,1],D[15,4],D[15,5],D[15,6]
3300 DATA 0.7,0.7,0.1,0
3310 READ D[16,1],D[16,4],D[16,5],D[16,6]
3320 DATA 0.5,0.3,0.8,0.1
3330 IF R[I1]>0 THEN 3360
3340 PRINT "WPN"I1"OUT"
3350 GOTO 3430
3360 FOR J6=1 TO 6
3370 IF J6=2 OR J6=3 THEN 3410
3380 GOSUB 2530
3390 IF A4<0.0001 OR T4*A4<D[I1,J6] THEN 3410
3400 K[I1,J6]=T4*A4*(1-(1-D[I1,J6]/(T4*A4))^(H5*A4))+K[I1,J6]
3410 NEXT J6
3420 R[I1]=R[I1]-H6
3430 RETURN
```

c. <u>Data Variables.</u>

D(i,j) Adjusted probability of kill given hit.

d. <u>Defined and Computed Variables.</u>

I1 Firing weapon number, 1-20

K(i,j) Accumulated number of kills by weapon i, i = 1-20, against weapon j, j = 1-6

R(i) Remaining load per weapon, 1-20.

e. <u>Modeling.</u>

(1) The remaining load per weapon R(i) is accumulated by subtracting the number of firings per period H6.

(2) The total number of kills per weapon and per target J6 is found from the total number of targets acquired T4, the fraction of firings to the target type A4, the total number of hits H5, and the probability of kill given a hit on each target type by the firer, by:

$$K^*(I1,J6) = T4 \cdot A4 \cdot \left[1 - \left(1 - \frac{D(I1,J6)}{T4 \cdot A4}\right)^{H5 \cdot A4}\right]$$

The variable K(i,j) is required in the updating of forces routine.

f. <u>Notes</u>. Since the probabilities of hit were computed without regard to particular target activity, size, posture, etc., the probability of kill given hit should reflect these considerations between target types with respect to relative size.

B-12. ARTILLERY.

a. Purpose. This subroutine handles the attrition due to artillery. Artillery can be employed in preparation before the battle and at the start of any iteration. The model also suggests a necessary allocation of fires to achieve desired damage (if possible).

b. Artillery Subroutine Listing.

```
3440 REM-ARTY
3450 IF N[I0,2*J0] <= 0 THEN 4120
3460 PRINT "RORD DMG FR"
3470 INPUT D7
3480 RESTORE 3540
3490 FOR I9=1 TO 6
3500 FOR J9=1 TO 6
3510 READ C[I9,J9],D[I9,J9]
3520 NEXT J9
3530 NEXT I9
3540 DATA 6.25,7.25,40,15,20,5.25,20,6.5,25,4.75,25
3550 DATA 0,25,0,40,0,20,0,20,0,25,0,25
3560 DATA 7,25,9.25,40,17.5,20,0,20,0,25,0,25
3570 DATA 7,25,9.25,40,17.5,20,6,20,8.5,25,6,25
3580 DATA 7.25,9.25,40,17.5,20,19,20,23,25,21,25
3590 DATA 7,25,9.25,40,17.5,20,19,20,23,25,21,25
3600 I7=I0-7
3610 I8=I7+3*(J0-1)
3620 FOR I4=1 TO 6
3630 IF I4=2 THEN 3670
3640 J[I4]=FNF(I4)
3650 IF J[I4]<1 THEN 3670
3660 J[I4]=0.99
3670 NEXT I4
3680 RESTORE 3740
3690 FOR I9=1 TO 3
3700 FOR J9=1 TO 2
3710 READ C[I9,J9],G[I9,J9],D[I9,J9]
3720 NEXT J9
3730 NEXT I9
3740 DATA 0.3,0.5,2
3750 DATA 0.2,0.05,4
3760 DATA 0.3,0.5,2
3770 DATA 0.2,0.05,4
3780 DATA 0.3,0.5,2
3790 DATA 0.2,0.05,4
3800 L7=C[I7,J0]*(G[I7,J0]+(1-G[I7,J0])*T0/D[I7,J0])
3810 IF L7<C[I7,J0] THEN 3830
3820 L7=C[I7,J0]
3830 P7=1-EXP(-L7*T1)
```

```
3840 IF P7=0 THEN 4120
3850 J7=6-2*J0
3860 FOR I9=1 TO 6
3870 IF I9=2 THEN 3890
3880 A[I9]=P7*N[I9,J7]
3890 NEXT I9
3900 A[2]=0
3910 PRINT "TGTS FOUND/DESIRED RDS BY"I0","J0
3920 WRITE (15,4350)A[1],A[2],A[3],A[4],A[5],A[6]
3930 MAT H=ZER
3940 FOR I9=1 TO 6
3950 IF I9=2 THEN 4000
3960 IF A[I9] <= J[I9] OR J[I9]<0.00001 THEN 4000
3970 J9=1+LOG(1-D7)/LOG(1-J[I9]/A[I9])
3980 IF J9>32766 THEN 4000
3990 H[I9]=INT(J9)
4000 NEXT I9
4010 FOR I9=1 TO 6
4020 PRINT H[I9];
4030 NEXT I9
4040 PRINT
4050 PRINT "RDS BY TGT"
4060 INPUT H[1],H[2],H[3],H[4],H[5],H[6]
4070 FOR I9=1 TO 6
4080 IF I9=2 OR H[I9]*A[I9]=0 THEN 4110
4090 J9=I0+10*(J0-1)
4100 K[J9,I9]=A[I9]*(1-(1 J[I9]/A[I9])^H[I9])+K[J9,I9]
4110 NEXT I9
4120 RETURN
4130 DEF FNF(J7)
4140 RESTORE 4180
4150 FOR I9=1 TO 6
4160 READ A[I9],B[I9]
4170 NEXT I9
4180 DATA 78,60,50,120,90,90,33,100,40,110,250,260
4190 FOR I9=1 TO 6
4200 READ S[I9,1],S[I9,2]
4210 NEXT I9
4220 DATA 35,40,0,0,0,40,35,40,35,40,35,40
4230 F=(1-EXP((-0.5)*(S[J7,3-J0]^2/(A[I9]^2+B[I9]^2))))*(D[J7,I9]/N[J7,I9])^2
4240 RETURN F
```

c. Data Variables.

C(i,j)	Lethal radius of jth artillery (1-6) versus ith target (1-6) (first use)
D(i,j)	Radius of coverage of jth artillery (1-6) versus ith target (1-6) (first use)
C(i,j)	Maximum detection rate, targets per minute, of (i,j) artillery i = 1, 2, 3, j = 1, 2 (second use)
G(i,j)	Initial detection degradation factor of (i,j) artillery i = 1, 2, 3, j = 1, 2
D(i,j)	Battle time when C(i,j) is realized (second use)
A(i), B(i)	Weapon dispersion, aim/location errors
S(i,j)	Individual target unit radius, i = 1-6, j = 1, 2

d. Defined and Computed Variables.

D7	Required damage fraction
I8	Artillery number, 1-6
I7	Artillery number, 1-3
J(i) = F	Probability of kill of artillery (I0,J0) versus target i
L7	Detection rate in targets per minute at T0
P7	Probability of detecting targets in time interval from T0 to T0 + T1
J7	4 if J0 = 1, 2 if J0 = 2
A(i)	Number of targets detected of type i from T0 to T0 + T1
J9 = H(i)	Number of rounds required for D7 fractional damage to target type i (if possible) (first use)
J9	8, 9, 10 for Blue artillery; 18, 19, 20 for Red artillery (second use)
J7	Target type number in "F" function.

e. Modeling.

(1) The probability of target kill by each round is computed first. The probability of hit is found by assuming a normal distribution on weapon, aim/location errors. In the probability of kill given a hit computations, it is assumed that the target is located uniformly throughout the area of coverage. Thus:

$$F^* = 1-e^{-\frac{1}{2} \cdot S(J7,\ 3-J0)^2/(A(I8)^2 + B(I8)^2)}$$

$$F = F^* \cdot \left(\frac{C(J7,\ I8)}{D(J7,\ I8)}\right)^2$$

(2) Secondly, the number of targets detected is computed. The rate of detection is a linear regression between the initial degraded rate at T0 = 0 and the maximum rate at T0 = C(i,j). The probability of detecting targets between T0 and T0 + T1 is computed as in paragraph B-5.

$$L7 = \begin{cases} C(I7,\ J0) \cdot \left(G(I7,\ J0) + \dfrac{(1-G,(I7,\ J0)) \cdot T0}{D(I7,\ J0)}\right) & \text{if } T0 \le D(I7,\ J0) \\ C(I7,\ J0) & \text{if } T0 > D(I7,\ J0) \end{cases}$$

$$P7 = 1-e^{-L7 \cdot T1}$$

$$A(i) = P7 \cdot N(i,\ J7)$$

(3) By back solving, the number of rounds required to do damage of D7, if possible, to each target is:

$$E8 = H(i) = 1 + \frac{\mathrm{Log}\ (1-D7)}{\mathrm{Log}\left(1-\dfrac{J(i)}{A(i)}\right)}$$

(4) With the above computations, the number of kills of each target i by each artillery type J9 is simply:

$$K^* (J9, i) = A(i) \left(1 - \left(\frac{1-J(i)}{A(i)}\right)^{H(i)}\right)$$

f. Notes.

(1) This model assumes that the target units are sufficiently spread out and that each artillery round works independently and essentially only on one target unit.

(2) The code can easily be modified to print the number of targets found, by type, or the number of targets present, by type, instead of the number of rounds required to achieve the input damage fraction. These alternatives may be desired if modeling a less discriminant allocation of fire capability.

(3) Another modification could be to replace A(i), the number of targets found, by a percentage of the number of targets present. This could be especially appropriate for the artillery preparation.

B-13. RESERVES COMMITMENT.

a. Purpose. This subroutine allows the addition of forces due to reserves, second echelons, etc., or the deletion of forces due to externally determined attrition such as close air support.

b. Reserves Commitment Subroutine Listing.

```
4250 REM-RES
4260 PRINT "RES 1ST FRC:"
4270 FOR I9=1 TO 10
4280 WRITE (15,4350)N[I9,2]:
4290 NEXT I9
4300 PRINT
4310 WRITE (15,*)"RES 2ND FRC:"
4320 FOR I9=1 TO 10
4330 WRITE (15,4350)N[I9,4]:
4340 NEXT I9
4350 FORMAT 10F5.2,/
4360 PRINT
4370 PRINT
4380 PRINT "3L RES BY #"
4390 INPUT A[1],A[2],A[3],A[4],A[5],A[6],A[7],A[8],A[9],A[10]
4400 IF A[1]=0 THEN 4420
4410 R[1]=(A[1]*T[1]+N[1,2]*R[1])/(A[1]+N[1,2])
4420 IF A[4]=0 THEN 4440
4430 R[4]=(A[4]*T[4]+N[4,2]*R[4])/(A[4]+N[4,2])
```

```
4440 IF A[5]=0 THEN 4460
4450 R[5]=(A[5]*T[5]+N[5,2]*R[5])/(A[5]+N[5,2])
4460 FOR I9=1 TO 10
4470 N[I9,2]=N[I9,2]+A[I9]
4480 N[I9,1]=N[I9,1]+A[I9]
4490 NEXT I9
4500 PRINT "NEW BL FRC:"
4510 FOR I9=1 TO 10
4520 WRITE (15,4350)N[I9,2]:
4530 NEXT I9
4540 PRINT
4550 PRINT "RD RES BY #"
4560 INPUT A[1],A[2],A[3],A[4],A[5],A[6],A[7],A[8],A[9],A[10]
4570 IF A[1]=0 THEN 4590
4580 R[11]=(A[1]*T[11]+N[1,4]*R[11])/(A[1]+N[1,4])
4590 IF A[4]=0 THEN 4610
4600 R[14]=(A[4]*T[14]+N[4,4]*R[14])/(A[4]+N[4,4])
4610 IF A[5]=0 THEN 4630
4620 R[15]=(A[5]*T[15]+N[5,4]*R[15])/(A[5]+N[5,4])
4630 IF A[6]=0 THEN 4650
4640 R[16]=(A[6]*T[16]+N[6,4]*R[16])/(A[6]+N[6,4])
4650 FOR I9=1 TO 10
4660 N[I9,4]=N[I9,4]+A[I9]
4670 N[I9,3]=N[I9,3]+A[I9]
4680 NEXT I9
4690 PRINT "NEW RD FRC:"
4700 FOR I9=1 TO 10
4710 WRITE (15,4350)N[I9,4]:
4720 NEXT I9
4730 PRINT
4740 GOSUB 6040
4750 GOSUB 4770
4760 RETURN
```

c. Data Variables. None.

d. Defined and Computed Variables.

A(i) Number of weapon additions/deletions, 1-10

R(i) Remaining load per weapon, 1-20

e. Modeling. This routine is a bookkeeping exercise. The new forces are added, and the new weapon load is the weighted average of remaining loads and basic loads.

B-14. BATTLE STATUS.

a. Purpose. This routine prints out the following battle information in order.

(1) Battle status time: T0, and range: R1

(2) Surviving total Blue force: B4

(3) Surviving total Red force: D4

(4) Percent Blue survivors: $100 \cdot B4/B1$

(5) Percent Red survivors: $100 \cdot D4/D1$

(6) Surviving maneuver force ratio difference (SMFRD):

$$\frac{B4}{B1} - \frac{D4}{D1}$$

(7) Loss exchange ratio (LER): D5/B5

(8) Fractional exchange ratio (FER):

$$\frac{D5/B5}{D1/B1}$$

(9) Cumulative Red losses: D5

(10) Cumulative Blue losses: B5

(11) Attacker's advance rate: V5

(12) Distance advanced: R2

b. Battle Status Subroutine Listing.

```
4770 REM STAT
4780 GOSUB 5950
4790 PRINT
4800 PRINT "STATS-TIME"T0","RNG"R1
4810 PRINT "BL FRC"B4
4820 PRINT "RD FRC"D4
4830 PRINT "% BL SURV"100*B4/B1
4840 PRINT "% RD SURV"100*D4/D1
4850 PRINT "SFRD"B4/B1-D4/D1
```

```
4860 IF B5>0 THEN 4890
4870 PRINT "LER&FER NOT DEFINED"
4880 GOTO 4910
4890 PRINT "LER"D5/B5
4900 PRINT "FER"(D5*B1)/(D1*B5)
4910 PRINT "RD CUM LOSS"D5
4920 PRINT "BL CUM LOSS"B5
4930 PRINT "ADV RATE"V5
4940 PRINT "DIST ADV"R2
4950 RETURN
```

B-15. ATTACKER'S ADVANCE.

a. Purpose. This subroutine computes the attack rate and the distance advanced. The attack rate depends upon the ratio of the cumulative loss rate of Red over Blue.

b. Advance Rate Subroutine Listing.

```
4960 REM-ADV
4970 V8=20/60
4980 GOSUB 5950
4990 V5=V0
5000 IF T0=0 OR D5=0 THEN 5070
5010 I9=V0*(2*(B5/B1)/(D5/D1)-1)
5020 V5=V8
5030 IF V8 <= I9 THEN 5070
5040 V5=I9
5050 IF 0<V5 THEN 5070
5060 V5=0
5070 R2=V5*T1
5080 IF M1=0 THEN 5110
5090 V5=R2=0
5100 M1=0
5110 RETURN
```

c. Data Variables.

V8 Maximum attack rate possible in kilometers per minute.

d. Defined and Computed Variables.

V5, I9 Attack rate

R2 Distance advanced

M1 See FASCAM, Paragraph B-19.

e. Modeling.

(1) The rate of advance is computed as:

$$I9 = V0 \left(2 \cdot \frac{B5/B1}{D5/D1} - 1\right)$$

$$V5 = \begin{cases} 0 & \text{if } I9 < 0 \\ I9 & \text{if } 0 \leq I9 \leq V8 \\ V8 & \text{if } I9 > V8 \end{cases}$$

For values of I9 between 0 and V8, the attack rate is a linear function of percent Blue loss/percent Red loss. When the ratio is one, or the cumulative loss rates are equal, then the attack rate is the initial rate of advance. However, if Red is losing forces at a cumulative rate of twice that of Blue, the ratio = ½, then the advance is stopped. The advance may restart upon Red reinforcements or a faster rate of Blue losses, for example due to Red artillery being called in.

(2) The distance advanced is simply the product of rate V5 in kilometers per minute times the time interval T1 in minutes.

f. Notes.

(1) The advance rate is sensitive to the stopping criterion mentioned in subparagraph e(1) above. The initial rate can be forced to continue by adding the line:

(4995) GO TO (5070).

(2) Other stopping criteria can be programmed; for example, for a 4 to 1 loss rate ratio before stopping, with a ratio of 1 for continuing initial attack rate, the line (5010) should be changed to:

(5010) I9 = V0* ((4/3*((B5/B1)/(D5/D1) - (1/3)).

For Blue attacking with a 1 to 2 ratio stopping criterion, line (5010) should be changed to:

(5010) I9 = V0* ((-1)*((B5/B1)/(D5/D1) - (-2)).

B-16. ATTACK HELICOPTERS.

a. Purpose. This subroutine computes the attrition of Red elements by Blue attack helicopters.

b. Attack Helicopter Subroutine Listing.

```
5120 REM AH
5130 IF N[2,2*J0] <= 0 THEN 5390
5140 PRINT "FR AH"J0"COMM/MIN,0-NO"
5150 INPUT E7
5160 IF E7=0 THEN 5390
5170 I1=2+10*(J0-1)
5180 GOSUB 1170
5190 IF T4=0 THEN 5390
5200 A[2]=0.75
5210 A[12]=0.75
5220 IF T4<A[I1] THEN 5390
5230 J7=6-2*J0
5240 I9=N[4,J7]+N[5,J7]+N[6,J7]+N[3,J7]
5250 I8=I9/D4
5260 IF J0=1 THEN 5280
5270 I8=(I9-N[6,2])/D4
5280 B7=1-I8*R1/3
5290 IF I8<0.99 AND B7>0 THEN 5310
5300 B7=0
5310 K7=T4*(1-(1-A[I1]/T4)^(N[2,2*J0]*E7*T1))
5320 FOR J9=1 TO 6
5330 IF J9=1 THEN 5370
5340 IF J9=2 OR (J9=6 AND J0=2) THEN 5380
5350 K[I1,J9]=(1-B7)*K7*N[J9,J7]/I9+K[I1,J9]
5360 GOTO 5380
5370 K[I1,J9]=B7*K7+K[I1,J9]
5380 NEXT J9
5390 RETURN
```

c. Data Variables.

A(i) Expected number of kills per attack helicopter per minute.

d. Defined and Computed Variables.

E7 Fraction of attack helicopter committed per minute

I9 Total number of Red air defense and soft targets

I8 Ratio of I9 to total targets

B7 Apportionment of total kills to Red tanks

K7 Number of attack helicopter kills during present time step.

e. Modeling.

(1) The apportionment of kills to tanks at range R1 is computed by the equation:

$$B7 = 1 - I8 \cdot R1/3.$$

In the usual case of R1 < 3 there is a preference of tanks for targets over the rest of the vehicles.

(2) The total number of kills by attack helicopters from T0 to T0 + T1 is:

$$K7 = T4 \left(1 - \left(1 - \frac{A(i)}{T4} \right)^{N(2,2J0) \cdot E7 \cdot T1} \right)$$

(3) Kills for hard targets are accumulated by:

$$K(I0,J9) = B7 \cdot K7 + K(I0,J9).$$

The kills for air defense and soft targets are accumulated by:

$$K(I0,J9) = (1-B7) \cdot K7 \cdot N(J9,4)/I9 + K(I0,J9).$$

N(J9,4)/I9 gives the fraction of each type of air defense or soft target to total targets possible.

f. Notes.

(1) Modifications to allow air-to-air or interdiction raid against rear type elements would probably be too extensive considering present space restrictions.

(2) The variable E7 with S7 presently reflects that all committed attack helicopters are popping up as well as on station at the iteration. E7 could be reduced if the intent is to have the helicopters on station and relocating between popups a given percent of the time.

B-17. AIR DEFENSE.

a. Purpose. This subroutine calculates the attrition of Blue helicopters by Red air defense. There is only one type of air defense in the model.

b. Air Defense Subroutine Listing.

```
5400 REM AD
5410 J7=6-2*J0
5420 IF N[3,2*J0] <= 0 OR N[2,J7] <= 0 THEN 5520
5430 PRINT "AD"J0"AVAIL/MIN,0-NO"
5440 INPUT E8
5450 IF E7=0 OR E8=0 THEN 5520
5460 I1=3+10*(J0-1)
5470 A[3]=0.05
5480 A[13]=0.06
5490 I9=E7*N[2,J7]
5500 IF A[I1]>I9 THEN 5520
5510 K[I1,2]=I9*(1-(1-A[I1]/I9)^(N[3,2*J0]*E8*T1))+K[I1,2]
5520 RETURN
```

c. Data Variables.

A(i)   Number of helicopter kills per air defense per minute.

d. Defined and Computed Variables.

E8   Fraction of air defense available per minute

I9   Total number of AH present

K(13,2)   Cumulative kills of helicopters by air defense.

e. Modeling. The number of kills each time period is:

$$I9 \cdot \left(1-\left(1-\frac{A(i)}{I9}\right)^{N(3,2\ \cdot\ J0)\cdot E8\cdot T1}\right)$$

f. Notes.

(1) The input data can reflect generically an array air defense with proper preprocessing.

(2) The modifications for air defense to be employed in a direct fire ground role would be too great for present memory restrictions.

(3) The attack helicopter routine must be accessed for E7 in line (5340) to be properly defined.

(4) The air defense routine has no explicit dependence on line of sight or detection of the attack helicopters. Thus, these factors must be accounted for in E8, availability, or K7, kills per minute. Alternatively, the code could be modified to compute line of sight and number of targets (helicopters) detected.

B-18. CANNON LAUNCHED GUIDED PROJECTILES (CLGP).

a. Purpose. This subroutine computes the Copperhead (i.e., CLGP) kills on each opposing weapon type. It apportions the total CLGP kills to tanks to reflect a preference for tanks at ranges less than 3 kilometers.

b. CLGP Subroutine Listing.

```
5530 REM-CLGP
5540 IF N[6,2*J0] <= 0 THEN 5780
5550 PRINT "ROUNDS CONTROL/MIN,0-NO"
5560 INPUT E7
5570 IF E7=0 THEN 5780
5580 I1=6
5590 GOSUB 1170
5600 IF T4=0 THEN 5780
5610 I7=N[3,4]+N[4,4]+N[5,4]+N[6,4]
5620 I8=I7/D4
5630 B7=1-I8^1/3
5640 IF I8<0.99 AND B7>0 THEN 5660
5650 B7=0
5660 S7=0.25
5670 GOSUB 2030
5680 S7=S7*(1-S4)
5690 IF T4<S7 THEN 5780
5700 K7=T4*(1-(1-S7/T4)^(N[6,2*J0]*E7*T1))
5710 FOR J9=1 TO 6
5720 IF J9=1 THEN 5760
5730 IF J9=2 THEN 5770
5740 K[I1,J9]=(1-B7)*K7*N[J9,4]/I7+K[I1,J9]
5750 GOTO 5770
5760 K[I1,J9]=B7*K7+K[I1,J9]
5770 NEXT J9
5780 RETURN
```

c. Data Variables.

S7 Maximum CLGP performance in kills per round per GLLD

d. Defined and Computed Variables.

E7 Number of rounds controlled per GLLD per minute

I7 Number of AD plus Red soft targets

I8 Ratio of I7 to total targets

B7 Apportionment of total kills to Red tanks

K7 Number of CLGP kills during present time step.

e. Modeling.

(1) The apportionment of kills to tanks at range R1 is computed by the following equation:

$$B7 = 1-(I8)(R1/3)$$

where I8 is as defined above. In the usual case of R1 < 3 there is a preference of tanks for targets over the rest of the vehicles.

(2) The maximum performance of CLGP is degraded if the GLLD is suppressed by the following:

$$S7 = S7(1-S4)$$

where S4 is found in the suppression formula.

(3) The total number of kills by CLGP from T0 to T0 + T1 is:

$$K7 = T4\left(1-\left(1-\frac{S7}{T4}\right)^{N(I0,2J0)\cdot E7\cdot T1}\right)$$

(4) Kills for hard targets are accumulated by:

$$K(I0,J9) = B7 \cdot K7 + K(I0,J9)$$

Kills for soft targets and AD are accumulated by:

$$K(I0,J9) = (1-B7) \cdot K7 \cdot N(J9,4)/I7 + K(I0,J9)$$

N(J9,4)/I7 gives the fraction of each type of AD or soft target to total targets possible.

B-19. FASCAM.

a. Purpose. This subroutine calculates the attrition due to FASCAM minefield for either the bull-through tactic or employment of plows.

b. FASCAM Subroutine Listing.

```
5790 REM-FAS
5800 IF N[7,2*J0] <= 0 THEN 5940
5810 PRINT "#FIELDS,1-PLOW/0-BULL"
5820 INPUT I8,M1
5830 IF I8=0 THEN 5940
5840 I7=0.05
5850 E8=EXP(-I7*R1)
5860 K7=0.5/113
5870 IF M1=0 THEN 5890
5880 K7=0.25/113
5890 M7=N[1,4]+N[5,4]+N[6,4]
5900 K8=E8*I8*K7*M7
5910 K[I0,1]=K8*N[1,4]/M7+K[I0,1]
5920 K[I0,5]=K8*N[5,4]/M7+K[I0,5]
5930 K[I0,6]=K8*N[6,4]/M7+K[I0,6]
5940 RETURN
```

c. Data Variables.

I7 Terrain parameter used in probability of entering minefield

K7 Number of kills per target per field (depends on breach tactic).

d. Defined and Computed Variables.

I8 Number of standard 300m x 300m, 90-mine FASCAM minefields

M1 1 = plow tactic, 0 = bull tactic

E8 Probability of entering a minefield

M7 Number of vehicles attempting to breach the field

K8 Total number of kills due to the minefields.

e. Modeling.

(1) The probability of entering the minefield is a function of range:

$$E8 = e^{-I7 \cdot R1}$$

(2) The total number of kills is:

$$K8 = E8 \cdot I8 \cdot K7 \cdot M7$$

(3) In computing the attrition to each vehicle type, the model assumes that the tanks and BMPs breach the field while the BRDMs stay back in overwatch. Thus, the apportionment is proportional to the number of each type breaching the field. If the plow tactic is selected, then the Red advance will be slowed for one time step.

B-20. PRESENT BATTLE CUMULATIVES.

a. Purpose. This subroutine calculates the number of attritable elements remaining and lost.

b. Cumulative Subroutine Listing.

```
5950 REM-CUMS
5960 B5=D5=B4=D4=0
5970 FOR I7=1 TO 6
5980 B4=B4+N[I7,2]
5990 D4=D4+N[I7,4]
6000 NEXT I7
6010 B5=B1-B4
6020 D5=D1-D4
6030 RETURN
```

c. Data Variables. None.

d. Defined and Computed Variables.

B4 Present number of Blue attritable elements

D4 Present number of Red attritable elements

B5 Number of Blue losses

D5 Number of Red losses.

e. Modeling. This routine adds the present forces of types 1 through 6 (tanks, attack helicopters, air defense, ATGM, and GLLD).

B-21. INITIAL FORCE STRENGTHS.

a. Purpose. The number of attritable forces that have been committed are calculated in this subroutine.

b. Initial Force Strength Subroutine Listing.

```
6040 REM-INIT
6050 D1=B1=0
6060 FOR I7=1 TO 6
6070 B1=N[I7,1]+B1
6080 D1=N[I7,3]+D1
6090 NEXT I7
6100 PRINT "BL FRC COMM:"B1
6110 PRINT "RD FRC COMM:"D1
6120 RETURN
```

c. Data Variables. None.

d. Defined and Computed Variables.

B1 Total attritable Blue forces committed

D1 Total attritable Red forces committed.

e. Modeling. The forces committed of types 1 through 6 (tanks, attack helicopters, air defense, ATGM, and GLLD) are summed for each side.

B-22. UPDATE NUMBERS.

a. Purpose. The purpose of this subroutine is to calculate the number of present attritable targets. Also, the losses of each individual soft target during the previous time step are accumulated for calculating fractional losses to the system in the suppression routine.

b. Update Subroutine Listing.

```
6130 REM-UPD
6140 FOR I9=1 TO 6
6150 K9=K8=0
6160 FOR J9=1 TO 10
6170 K9=K9+K[J9+10,I9]
6180 K8=K8+K[J9,I9]
6190 NEXT J9
6200 N[I9,2]=N[I9,1]-K8
6210 N[I9,4]=N[I9,3]-K8
6220 IF N[I9,2]>0 THEN 6240
6230 N[I9,2]=0
6240 IF N[I9,4]>0 THEN 6260
6250 N[I9,4]=0
6260 NEXT I9
```

```
6270 FOR I9=1 TO 8
6280 O[I9]=-O[I9]
6290 NEXT I9
6300 FOR I9=1 TO 10
6310 FOR J9=4 TO 6
6320 O[J9-3]=O[J9-3]+K[I9+10,J9]
6330 O[J9]=O[J9]+K[I9,J9]
6340 NEXT J9
6350 O[7]=O[7]+K[I9+10,1]
6360 O[8]=O[8]+K[I9,1]
6370 NEXT I9
6380 RETURN
```

c. Data Variables. None.

d. Defined and Computed Variables.

K9 Cumulative losses for Blue weapon I9 by all Red systems

K8 Cumulative losses for Red weapon I9 by all Blue systems

O(i) Losses to the ith system during the previous time step for tanks and for soft targets 4, 5, and 6.

e. Modeling. The losses to the attritable systems are totaled from the K (killer-victim) matrix.

APPENDIX C

GROUND COMBAT MODEL OUTPUT

C-1. PURPOSE. This appendix describes the Ground Combat Model output, in particular the graphs of the measures of effectivensss (MOE) available. The model program stores relevant output in a transformed way on a common block while executing. This common block is then stored on a file after the run is terminated and used as input for a graphing program. These MOEs may then be plotted versus time individually or with MOEs from the same run or from different runs.

C-2. MEASURES OF EFFECTIVENESS (MOE). The following MOE are calculated by the model.

a. Distance advanced (per time period)

b. Present Blue force

c. Present Red force

d. Battle range (in kilometers)

e. Attacker's advance rate (per minute)

f. Total committed Blue forces

g. Total committed Red forces

h. Percent Blue surviving

i. Percent Red surviving

j. Surviving maneuver force ratio difference (SMFRD)

k. Loss exchange ratio (LER)

l. Fractional exchange ratio (FER)

m. Cumulative Blue losses

n. Cumulative Red losses

o. Percent Blue losses

p. Percent Red losses.

C-3. INPUT DATA.

a. The input data (the A array) are obtained from the X array of the model (see common statements in code). Because of the need to conserve memory by using integer numbers, a conversion on data in the model was made in order to prevent the loss of all decimal places.

b. The data in the A matrix are stored by time period. Converted initial data are assigned to row 1. Data for the ith time period or iteration are assigned to row i+1.

c. Following is a list of the data, for each iteration, and their conversions. The X's and Y's are the actual values, and the A's are the converted data that are passed.

(1)	Time	X(I)	= A(I,1)/100
(2)	Present Blue forces	Y(I,2)	= A(I,2)/100
(3)	Present Red forces	Y(I,3)	= A(I,3)/100 + 325
(4)	Present battle range (in km)	Y(I,4)	= A(I,4)/1000
(5)	Attacker's advance rate (per min)	Y(I,5)	= A(I,5)/1000
(6)	Total committed Blue forces	Y(I,6)	= A(I,6)/100
(7)	Total committed Red forces	Y(I,7)	= A(I,7)/100 + 325

C-4. MEASURES OF EFFECTIVENESS (MOE) CALCULATIONS. Calculations for selected MOEs appear below.

a. Distance Advanced. Y(I,1) = Y(I,5)*(X(2)-X(1))

Distance advanced = advance rate (km/min) X length of time period (min). If the time period equals 1 minute, then distance advanced and attack rate are numerically equal.

b. SMFRD. Y(I,10) = Y(I,2)/Y(I,6) - (Y(I,3)/Y(I,7)

$$\text{SMFRD} = \frac{\text{Present Blue forces}}{\text{Committed Blue forces}} - \frac{\text{Present Red forces}}{\text{Committed Red forces}}$$

For SMFRD the X-axis is drawn to intersect the Y-axis at Y = 0.

c. LER. Y(I,11) = [Y(I,7)-Y(I,3)] / [Y(I,6)-Y(I,2)]

LER = ratio of Red losses to Blue losses.

d. FER. Y(I,12) = (Y(I,7)-Y(I,3))/(Y(I,6)-Y(I,2))/Y(I,7)/Y(I,6)

$$\text{FER} = \frac{\text{LER}}{\text{Committed Red forces/Committed Blue forces}}$$

C-5. SAMPLE OUTPUT. Figure C-1 is the output from two iterations of the model. It is not part of an actual run but is a trial of all options. The N and K arrays need not be printed each iteration. Figure C-2 is a listing of the operations required to produce two graphs on the same axes. Figure C-3 is a copy of the graphing program. A plot of the MOE, percent Blue survivors, from two different runs and a plot of the two MOEs, percent Blue survisors and percent Red survivors, from the same run are shown in chapter 2.

```
RUN
INP INIT BL FORCE (1-10)?10,18,0,25,20,5,1,1,1,1
INP INIT RE FORCE (1-10)?40,0,5,20,60,40,0,1,1,1
INP INIT BTL RNG?2.5
INP INIT ATK RATE?.2
INP TIME STEP?1
BLUE FORCES COMMITTED:  78.000
RED FORCES COMMITTED:  165.000
INP PRF BRDM V BMP,TOW V DR? .6, .8

ITERATION 1.000
INP 1-SUP,0-NOT?1
INP(0,0)FOR NO ARTY
INP ARTY #,1-BL/2-RE?10,2
INPUT RQRD DMG FR?.05
# DESIRED RDS BY 10.000, 2.000 vs. TGTS:
 158.000     0.000     0.000     355.000     145.000     101.000
INP FIRE #'s BY TGT?80,0,0,160,80,80
1-PREP OVER, 0-NOT?1
ARTY PREP OVER
INP(0,0) FOR NO ARTY
INP ARTY #,1-BL/2-RE?8,1
INPUT RQRD DMG FR?.05
# DESIRED RDS BY 8.000    ,  1.000  VS TGTS:
 1308.000     0.000     0.000    1080.000     2075.000     1383.000
INP FIRE #'S BY TGT?18,0,0,18,36,36
INP(0,0) FOR NO ARTY
INP ARTY #,1-BL/2-RE?0,0
FRAC AH COMM PER MIN,)-NONE?.3
INP AD AVAIL PER MIN,0-NO AD?.5
INP #FIELDS,&1-PLOW OR 0-BULL?5,0
INP #RNDS CONTROL/MIN,0-NO PLAY?3
INP 1 FOR STAT?1
STATS-TIME 1.000   ,RNG 2.300
BLUE FORCE 76.385
RED FORCES 152.401
% BL SURV= 97.930
% RED SURV= 92.364
SMFRD= 0.056
LER= 7.802
FER= 3.688
RED CUM LOSSES= 12.599
BLUE CUM LOSSES= 1.615
```

Figure C-1. Two-iteration model run (continued next page)

```
ATK ADV RATE 0.200
DIST ADV 0.200
INP 1-RES COMMIT?1
PRES BLUE FORCE:
     9.17   17.85   0.00   24.40   19.98   5.00   1.00  1.00  1.00   1.00
PRES RED FORCE:
    36.01    0.00   4.87   17.47   56.44  37.62   0.00  1.00  1.00   1.00

INP BL RES BY #?0,0,0,0,0,0,0,0,0,0
NEW RED FORCE:
    46.01    0.00   4.87   17.47   96.44  57.62   0.00  1.00  1.00   1.00
BLUE FORCES COMMITTED:  78.000
RED FORCES COMMITTED:  245.000
STATS-TIME 1.000    ,RNG 2.300
BLUE FORCE 76.385
RED FORCES 232.401
% BL SURV= 97.980
% RED SURV= 94.858
SMFRD= 0.031
LER= 7.802
FER= 2.484
RED CUM LOSSES= 12,599
BLUE CUM LOSSES= 1.615
ATK ADV RATE 0.200
DIST ADV 0.200

ITERATION 2,000
INP 1-SUP,0-NOT?STOP
MATPRINTN
  10.000     9.166     50.000     46.009
  18.000    17.851      0.000      0.000
  0.000      0.000      5.000      4.866
  25.000    24.395     30.000     27.467
  20.000    19.976    100.000     96.437
   5.000     4.997     60.000     57.622
   1.000     1.000      0.000      0.000
   1.000     1.000      1.000      1.000
   1.000     1.000      1.000      1.000
   1.000     1.000      1.000      1.000
```

Figure C-1. Two-iteration model run (continued)

MATPRINTK

0.556	0.000	0.000	0.652	0.237
0.158				
0.970	0.000	0.066	0.266	0.797
0.532				
0.000	0.000	0.000	0.000	0.000
0.000				
0.690	0.000	0.000	1.341	0.537
0.358				
0.000	0.000	0.000	0.000	0.000
0.000				
0.989	0.000	0.068	0.271	0.813
0.542				
0.781	0.000	0.000	0.000	1.171
0.781				
0.004	0.000	0.000	0.002	0.007
0.007				
0.000	0.000	0.000	0.000	0.000
0.000				
0.000	0.000	0.000	0.000	0.000
0.000				
0.027	0.000	0.000	0.041	0.003
0.001				
0.000	0.000	0.000	0.000	0.000
0.000				
0.000	0.149	0.000	0.000	0.000
0.000				
0.709	0.000	0.000	0.228	0.007
0.000				
0.095	0.000	0.000	0.331	0.009
0.000				
0.000	0.000	0.000	0.000	0.000
0.000				
0.000	0.000	0.000	0.000	0.000
0.000				
0.000	0.000	0.000	0.000	0.000
0.000				
0.000	0.000	0.000	0.000	0.000
0.000				
0.003	0.000	0.000	0.006	0.006
0.002				

Figure C-1. Two-iteration model run (continued)

```
CONT
?1
INP(0,0)FOR NO ARTY
INP ARTY #,1-BL/2-RE?0,0
FRAC AH COMM PER MIN,0-NONE?.3
INP AD AVAIL PER MIN,0-NO AD?.5
INP #FIELDS, &1-PLOW OR 0-BULL?0,0
INP #RNDS CONTROL/MIN,0-NO PLAY?3
STATS-TIME 2.000   ,RNG 2.300
BLUE FORCE 74.255
RED FORCES  215.425
% BL SURV= 95.198
% RED SURV= 87.929
SMFRD= 0.073
LER= 7.897
FER= 2.514
RED CUM LOSSES = 29.575
BLUE CUM LOSSES= 3.745
ATK ADV RATE 0.000
DIST ADV 0.000
RED SLOWED
INP 1 FOR STAT?0
INP 1-RES COMMIT?0

ITERATION 3,000
INP 1-SUP,0-NOT?STOP
MATPRINTN
```

10.000	8.345	50.000	40.515
18.000	17.706	0.000	0.000
0.000	0.000	5.000	4.754
25.000	23.290	30.000	22.457
20.000	19.924	100.000	92.457
5.000	4.989	60.000	55.244
1.000	1.000	0.000	0.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

Figure C-1. Two-iteration model run (concluded)

```
INPUT FILE #?2
MENU? 0=NO, 1=YES?0
ENTER OPTION # OF PLOT?8
ENTER THE MIN & MAX X?0,9
ENTER THE MIN, MAX & INCREMENT Y?0,100,25
LABEL Y AXIS?  0=NO, 1=YES?1
ENTER Y AXIS LABEL?  % SURVIVING
PLOT AGAIN? 0=NO, 1=YES, 2=SAME AXIS?2
PLOT SAME FILE? 0-NO  1-YES?1
MENU?  0=NO, 1=YES?0
ENTER OPTION # OF PLOT?9
```

Figure C-2. Graphing program operations

```
10 COM A[31,7]
20 DIM Y$[31,16],X$[31],J$[30]
30 R3=0
40 FIXED 2
50 DISP "INPUT FILE #";
60 INPUT A1
70 LOAD  DATA A1
80 MAT Y=ZER
90 MAT X=ZER
100 FOR I=1 TO 31
110 X[I]=A[I,1]/100
120 Y[I,2]=A[I,2]/100
130 Y[I,3]=A[I,3]/100+325
140 Y[I,4]=A[I,4]/1000
150 Y[I,5]=A[I,5]/1000
160 Y[I,6]=A[I,6]/100
170 Y[I,7]=A[I,7]/100+325
180 NEXT I
190 DISP "MENU? 0=NO,1=YES";
200 INPUT R4
210 IF R4=0 THEN 550
220 PRINT
230 PRINT "1-DISTANCE ADVANCED"
240 PRINT
250 PRINT "2-PRESENT BLUE FORCE"
260 PRINT
270 PRINT "3-PRESENT RED FORCE"
280 PRINT
290 PRINT "4-BATTLE RANGE"
300 PRINT
310 PRINT "5-ATTACKER'S ADVANCE RATE"
320 PRINT
330 PRINT "6-TOTAL COMMITTED BLUE FORCES"
340 PRINT
350 PRINT "7-TOTAL COMMITTED RED FORCES"
360 PRINT
370 PRINT "8-% BLUE SURVIVING"
380 PRINT
390 PRINT "9-% RED SURVIVING"
400 PRINT
410 PRINT "10-SMFRD(SURVIVING FORCE RATIO DIFF)"
420 PRINT
430 PRINT "11-LER"
440 PRINT
450 PRINT "12-FER(FRACTIONAL EXCHANGE RATIO)"
460 PRINT
```

Figure C-3. Graphing program (continued next page)

```
470 PRINT "13-CUM BLUE LOSSES"
480 PRINT
490 PRINT "14-CUM RED LOSSES"
500 PRINT
510 PRINT "15-% BLUE LOSSES"
520 PRINT
530 PRINT "16-% RED LOSSES"
540 PRINT
550 DISP "ENTER OPTION # OF PLOT";
560 INPUT B1
570 REM-B3=2 SKIPS LABELS
580 IF B3=2 THEN 1010
590 REM      AXIS DRAWING AND LABELING
600 DISP "ENTER THE MIN & MAX X";
610 INPUT M1,M2
620 M5=X[3]-X[2]
630 DISP "ENTER THE MIN,MAX &INCREMENT Y";
640 INPUT M3,M4,M6
650 W1=(M2-M1)/24
660 W2=(M4-M3)/18
670 SCALE M1-2.5*W1,M2+W1,M3-2.5*W2,M4+W2
680 IF B1=10 THEN 730
690 PLOT M2,M3
700 PLOT M1,M3
710 PLOT M1,M4,-1
720 GOTO 770
730 PLOT M2,0
740 PLOT M1,0
750 PLOT M1,M4,1
760 PLOT M1,M3,2
770 G1=M3
780 G2=M4
790 G3=M6
800 Z1=FNG0
810 G1=M1
820 G2=M2
830 G3=M5
840 Z1=FNG1
850 PLOT ((M1+M2)/2)-3*W1,M3-2.5*W2,1
860 LABEL (*,1.5,1.7,0,6/3)"TIME"
870 DISP "LABEL Y AXIS? 0=NO,1=YES";
880 INPUT B2
890 IF B2=0 THEN 980
900 DISP "ENTER Y AXIS LABEL";
910 INPUT J$
920 B4=LEN(J$)
930 PLOT -1,(M3+M4)/2+B4/4*W2,1
```

Figure C-3. Graphing program (continued)

```
940 FOR I=1 TO 34
950 CPLOT -1,-1
960 LABEL (*,1.5,1.7,0,6/3)J$[I,I]
970 NEXT I
980 PEN
990 IF M5=1 THEN 1010
1000 M2=M2/M5
1010 IF R1>10 THEN 1030
1020 GOTO R1 OF 1040,1470,1470,1470,1470,1470,1470,1090,1160,1230
1030 GOTO R1-10 OF 1280,1330,1380,1430,1090,1160
1040 REM DISTANCE ADVANCED
1050 FOR I=1 TO M2+1
1060 Y[I,1]=Y[1,5]*(Y[2]-X[1])
1070 NEXT I
1080 GOTO 1470
1090 REM %BL SURVIVING/OR/%BL LOSSES
1100 FOR I=1 TO M2+1
1110 Y[I,8]=100*Y[I,2]/Y[I,6]
1120 IF R1=8 THEN 1140
1130 Y[I,15]=100-Y[I,8]
1140 NEXT I
1150 GOTO 1470
1160 REM % RED SURVIVING/OR/% RL LOSSES
1170 FOR I=1 TO M2+1
1180 Y[I,9]=100*Y[I,3]/Y[I,7]
1190 IF R1=9 THEN 1210
1200 Y[I,14]=100-Y[I,9]
1210 NEXT I
1220 GOTO 1470
1230 REM SMF-D
1240 FOR I=1 TO M2+1
1250 Y[I,10]=Y[I,2]/Y[I,6]-Y[I,3]/Y[I,7]
1260 NEXT I
1270 GOTO 1470
1280 REM LER
1290 FOR I=2 TO M2+1
1300 Y[I,11]=(Y[I,7]-Y[I,3])/(Y[I,6]-Y[I,2])
1310 NEXT I
1320 GOTO 1470
1330 REM FER
1340 FOR I=2 TO M2+1
1350 Y[I,12]=((Y[I,7]-Y[I,3])/(Y[I,6]-Y[I,2]))/(Y[I,7]/Y[I,6])
1360 NEXT I
1370 GOTO 1470
1380 REM CUM BLUE LOSSES
1390 FOR I=2 TO M2+1
1400 Y[I,13]=Y[I,6]-Y[I,2]
```

Figure C-3. Graphing program (continued)

```
1410 NEXT I
1420 GOTO 1470
1430 REM CUM. FED LOSSES
1440 FOR I=2 TO M2+1
1450 Y[I,14]=Y[I,7]-Y[I,3]
1460 NEXT I
1470 REM PLOT GRAPHS
1480 PLOT Y[1],Y[1,R1],1
1490 FOR I=2 TO M2+1
1500 PLOT Y[I],Y[I,R1],2
1510 NEXT I
1520 PEN
1530 DISP "PLOT AGAIN?0=NO,1=YES,2=... ":
1540 INPUT B3
1550 IF B3=0 THEN 1750
1560 DISP "PLOT SAME FILE? 0-NO 1-YES":
1570 INPUT A2
1580 IF A2=0 THEN 50
1590 GOTO 190
1600 GOTO 1750
1610 REM  FNG DEF
1620 DEF FNG(Z1)
1630 P1=INTLGT(ABSG1+(ABSG2-ABSG1)*(ABSG2>ABSG1))
1640 P0=(P1<-1 OR P1>2)
1650 LABEL (*,1.5,1.7,Z1*PI/2,6/8)
1660 FOR K=G1 TO G2 STEP G3
1670 PLOT M1* NOT Z1+K*Z1,K* NOT Z1+M3*Z1,1
1680 CPLOT -7.3,-0.3
1690 LABEL (1700)K/( NOT P0+P0*10^P1)"-"
1700 FORMAT 2F7.2
1710 NEXT K
1720 IF P0=0 THEN 1740
1730 LABEL (*)" X10^"P1:
1740 RETURN 0
1750 END
```

Figure C-3. Graphing program (concluded)

APPENDIX D

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This report documents a quick-running, low-resolution ground combat model developed at the US Army Combined Arms Combat Development Activity (CACDA). This model determines firers, targets, engagements, attritions, data update, and specified output for each time step of a tank-antitank battle. A model overview is presented, and potential model applications are discussed. Data requirements, model mathematics, and computer coding are included. The model should be a useful tool for ranking weapon mixes to determine sets of best candidates used in an interactive gaming environment.

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